BP33

Vale of Glamorgan Council

Net Zero Carbon Buildings Feasibility Study and Cost Assessment

Architecture
Low Energy Consultancy
Civil Engineering
Structural Engineering
Urban Design

Contents

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Work Stages 1A - C

January 2024

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Section 1: Introduction

1.1 Introduction

Spring Design Consultancy Limited are appointed to assist Vale of Glamorgan Council in developing suitably evidenced Net Zero policy to guide, assess and determine applications for new-build residential and non-residential development within the emerging Replacement Local Development Plan 2021-2036.

This process has been divided into distinct work stages:

Work Stage 1	A - Policy Review
	B - Policy Approach
	C - Evidence Base
Work Stage 2	D - Methodologies
	E - Technical Feasibility
Work Stage 3	F - Cost Analysis
Work Stage 4	G - Evidence
	H - Cost Implications
	I - Scrutiny Skillset
Work Stage 5	Examination

This report presents the outcomes of Work Stage 1A - Policy Review, Work Stage 1B - Policy Approach and Work Stage 1C - Evidence Base.

1.2 Definitions

Clarity and consistency in the basic terminology used to discuss carbon and Net Zero is key to ensuring meaningful outcomes. Carbon Definitions for the Built Environment, Buildings and Infrastructure: Improving Consistency in Whole Life Carbon Assessment and Reporting (2023) is the result of extensive collaboration between CIBSE, ICE, IStructE, LETI, RIBA, RICS, UK GBC and WLCN and applies the following.

Carbon Definitions	
Term	Definition
Greenhouse Gases (GHG) *often 'carbon emissions' in general usage*	'Greenhouse Gases' are constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds.
Whole Life Carbon	'Whole Life Carbon' emissions are the sum total of all asset related GHG emissions and removals, both operational and embodied over the life cycle of an asset including its disposal (Modules: A0-A5; B1-B7; B8 optional; C1-C4, all including biogenic carbon, with A0 assumed to be zero for buildings). Overall Whole Life Carbon asset performance includes separately reporting the potential benefits or loads from future energy or material recovery, reuse, and recycling and from exported utilities (Modules D1, D2).
Embodied Carbon *or* Life Cycle Embodied Carbon	'Embodied Carbon' emissions of an asset are the total GHG emissions and removals associated with materials and construction processes throughout the whole life cycle of an asset (Modules A0-A5, B1-B5, C1-C4, with A0 assumed to be zero for buildings).
Upfront Carbon - Buildings	'Upfront Carbon' emissions are the GHG emissions associated with materials and construction processes up to practical completion (Modules A0-A5). Upfront carbon excludes the biogenic carbon sequestered in the installed products at practical completion.
Operational Carbon - Energy, Buildings	'Operational Carbon – Energy' (Module B6) are the GHG emissions arising from all energy consumed by an asset in-use, over its life cycle.

These definitions only address the GHGs with Global Warming Potential assigned by the Intergovernmental Panel on Climate Change (IPCC).

A0 is generally assumed to be zero for buildings, however infrastructure projects include ground investigations and activities associated with designing the asset in A0.

Demolition of existing structures or buildings must be separately identified and included within Module A5.

Net Zero Definitions	
Term	Definition
Net Zero (whole life) Carbon	A 'Net Zero (whole life) Carbon' Asset is one where the sum total of all asset related GHG emissions, both operational and embodied, over an asset's life cycle (Modules A0-A5, B1--B8, C1-C4) are minimized, which meets local carbon, energy and water targets or limits, and with residual 'offsets', equals zero. *To meet the requirements of 'Net Zero (whole life) Carbon' the definitions for 'Net Zero Upfront Carbon', Net Zero Embodied Carbon', 'Net Zero Capital Carbon', Net Zero operational Carbon - Energy', 'Net Zero Operational Carbon - Infrastructure', 'Net Zero In-Use Carbon Asset' and 'Net Zero Operational Carbon - Water' must also be individually met as applicable.*
Net Zero Carbon Embodied Carbon *or* Net Zero Life Cycle Embodied Carbon	A 'Net Zero Embodied Carbon' asset is one where the sum total of GHG emissions and removals over an asset's life cycle (Modules A0-A5, B1-B5 and C1-C4) are minimized, which meets local carbon targets or limits (e.g. $kgCO_2e/m^2$), and with additional 'offsets', equals zero.
Net Zero Upfront Carbon	A 'Net Zero Upfront Carbon' asset is one where the sum total of GHG emissions, excluding 'biogenic carbon', from Modules A0-A5 is minimized, which meets local carbon targets or limits (e.g kgCO2e/m2), and with additional 'offsets', equals zero.
Net Zero Operational Carbon - Energy	A 'Net Zero Operational Carbon – Energy' asset is one where no fossil fuels are used, all energy use (Module B6) has been minimized, meets the local energy use target or limit (e.g. kWh/m2/a) and all energy use is generated on- or off- site using renewables that demonstrate additionality. Direct emissions from renewables and any upstream emissions are 'offset'. *Direct emissions must include CH_4 and N_2O emissions from the combustion of biomass and biodiesel fuels. Upstream emissions include: direct and indirect emissions from energy generation and distribution, WTT emissions for energy consumed in the building and from energy generation and distribution.*
Net Zero Operational Carbon - Water	A 'Net Zero Operational Carbon - Water' asset is one where water use (Module B7) is minimized, meets local water targets or limits (e.g. litres/person/year) and where those GHG emissions arising from water supply and wastewater treatment are 'offset'.
Net Zero In-Use Asset	A 'Net Zero In-Use Carbon Asset' is one where on an annual basis the sum total of all asset related GHG emissions, both operational and embodied, (Modules B1-B8) are minimized, which meets local carbon, energy and water targets or limits, and with residual 'offsets', equals zero.

Additionality	Procurement of renewable energy for the asset's use which results in new installed renewable energy capacity that otherwise would not have occurred had the intervention not taken place.
Carbon Neutral	All carbon emissions are balanced with offsets based on carbon removals or avoided emissions.
Absolute Zero Carbon	Eliminating all carbon emissions without the use of credits.

Definitions pertaining specifically to infrastructure have been omitted as being beyond the scope of this project.

These definitions are designed to be technically robust and have been adopted by all collaborating organisations. They also reflect the assessment methodology outlined within Whole Life Carbon Assessment for the Built Environment 2nd Edition (2023).

An additional metric used with increasing frequency to assess building performance is energy use intensity (EUI) expressed in kWh/m²/yr. EUI is the annual measure of the total energy consumed within a building including all regulated and unregulated energy: it does exclude the charging of electric vehicles.

LETI Climate Emergency Design Guide (2021) states:

> *" 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.*
>
> *EUI is a metric that can be estimated at the design stage and very easily monitored in-use as energy bills are based on kWh of energy used by the building. This metric can be used to compare buildings of a similar type, to understand how well the building performs in-use. It includes all of the energy consumed in the building, such as regulated energy (heating, hot water, cooling, ventilation, and lighting) and unregulated energy (plug loads and equipment e.g. kitchen white goods, ICT/AV equipment). It does not include charging of electric vehicles.*
>
> *EUI can be expressed in GIA (Gross Internal Area) or NLA (Net Lettable Area). In this document the EUIs are expressed in GIA unless specified. EUI should replace carbon emission reductions as the primary metric used in policy, regulations, and design decisions."*

Section 2: Net Zero Policy - National

2.1 National Net Zero Policy

The UK is required to achieve Net Zero by 2050 (Climate Change Act as amended 2019), and 78% reductions[1] by 2035 (Climate Change Act as amended 2021) with 68% reductions by 2030 (COP26 Nationally declared contribution).The core Climate Change Act 2008 established an interim emissions reduction target of 34% by 2020: by 2019, before the complexities associated with assessing progress during COVID, UK attributed CO_2e emissions were estimated to have fallen by 40%[2].

While significant, emission reductions to date have been primarily driven by increased rates of efficiency and a relatively rapid decarbonisation of the electricity generation[3]. To achieve Net Zero by 2050 the built environment - representing approximately 25% of UK emissions[4] - requires the same principles of efficiency and decarbonisation to be urgently implemented.

Emissions in the built environment are primarily targeted by Building Regulations in England and Wales and the Building Warrant process in Scotland.

The Planning and Energy Act 2008 states:

> "*A local planning authority in England may in their development plan documents, a corporate joint committee may in their strategic development plan, and a local planning authority in Wales may in their local development plan, include policies imposing reasonable requirements for—*
> *(a) a proportion of energy used in development in their area to be energy from renewable sources in the locality of the development;*
> *(b) a proportion of energy used in development in their area to be low carbon energy from sources in the locality of the development;*
> *(c) development in their area to comply with energy efficiency standards that exceed the energy requirements of building regulations.*"

[1] Reductions are measured against the 1990 emission scenario.
[2] Committee on Climate Change (2021) Reducing UK emissions: 2021 Progress Report to Parliament [online]. London: Committee on Climate Change. Available from: www.theccc.org.uk/publications [Accessed 06.11.2023]. Page 8.
[3] *Ibid.*, Page 60.
[4] UK Green Building Council (11 November 2021) New report confirms that net zero is achievable for the built environment sector by 2050, but only with urgent government action [online]. Available from https://ukgbc.org/news/new-report-confirms-that-net-zero-is-achievable-for-the-built-environment-sector-by-2050-but-only-with-urgent-government-action/. [Accessed 14.11.2023].

The National Design Guide (2021) reinforces this advice, communicating a clear energy hierarchy for local authorities to consider when developing policy:

- reduce the need for energy through passive measures including form, orientation and fabric;
- use energy efficient mechanical and electrical systems, including heat pumps, heat recovery and LED lights; and
- maximise renewable energy especially through decentralised sources, including on-site generation and community-led initiatives[5].

This document also identifies that well-designed places and buildings employ the principles of whole life carbon assessment and the circular economy to reduce embodied carbon and construction waste[6].

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[5] Ministry of Housing, Communities and Local Government (2021) National Design Guide: Planning practice guidance for beautiful, enduring and successful places [online]. London: The Stationery Office. Available from: www.gov.uk/government/publications/national-design-guide [Accessed 06.11.2023]. Paragraph 138.
[6] *Ibid.*, Paragraph 142.

2.1.1 England

Approved Document L Volume 1 - Dwellings and 2 - Buildings other than dwellings - Conservation of fuel and power 2021 align with the policy objectives of reducing emissions, mandating reductions of 31% for dwellings and 27% for non-domestic builds. Consultation documents for the 2025 Building Regulations - the Future Homes Standard - suggest a 75% reduction in operational carbon emissions beyond 2013 standards: at present there are no details on whether embodied carbon will be assessed or regulated.

Current SAP methodology has been identified as unfit for purpose, failing to adequately predict or represent the actual performance of new buildings in operation[7]. RICS explicitly disqualify AD L calculations for energy modelling within whole life carbon assessments, stating that "[…] they are not a prediction of energy consumption."[8]

Making SAP and RdSAP 11 fit for Net Zero: A report for the Department for Business, Energy and Industrial Strategy (2021) is the result of an extensive review by a consortium led by Etude and draws much the same conclusion as RICS. This report makes 25 key recommendations that are necessary to improve the quality of output and align SAP with the drive toward Net Zero. It is unclear how many of these recommendations will be incorporated within SAP 11 - due for implementation in 2025[9] - and how successful it will therefore be in addressing these shortcomings.

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[7] UK Green Building Council (2021) Net Zero Whole Life Carbon Roadmap: A Pathway to Net Zero for the UK Built Environment [online]. London: UK Green Building Council. Available from: ukgbc.org/our-work-types/technical-report/ [Accessed 14.11.2023]. Page 40.

[8] RICS (2023) Whole life carbon assessment for the built environment 2nd edition [online]. London: Royal Institute of Chartered Surveyors (RICS). Available from: www.rics.org/profession-standards/rics-standards-and-guidance/sector-standards/construction-standards/whole-life-carbon-assessment [Accessed 16.10.2023]. Page .

[9] HM Government (20 December 2022) Guidance: Standard Assessment Procedure [online]. Available from: www.gov.uk/guidance/standard-assessment-procedure#future-developments---sap-11 [Accessed 16.11.2023].

2.1.2 Scotland

The Climate Change (Scotland) Act 2009 set a target of reducing greenhouse gas emissions, attributable to human activity, by at least 80% by 2050, with an interim target of a reduction of at least 42% by 2020. This was amended with the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 to increase the emission reduction targets to Net Zero by 2045.

Section 44 of the Act places a duty on every public body to act:

- in the way best calculated to contribute to the delivery of emissions targets in the Act;
- in the way best calculated to help deliver the Scottish Government's climate change adaptation programme; and
- in a way that it considers is most sustainable.

In response to Alex Rowley MSP Proposed Domestic Building Environmental Standards (Scotland) Bill (2022), Scottish Government committed to developing a Scottish equivalent of the Passivhaus standard that will apply to all building warrant applications received after 1st January 2025[10].

No draft policy is currently out for consultation, however it can be broadly assumed that as a minimum this will mandate a threshold for space heating demand of 15 kWh/m²/yr.

[10] Scottish Government (2023) Energy Standards Review - Scottish Passivhaus Equivalent: Working Group . Available from: www.gov.scot/groups/energy-standards-review-scottish-passivhaus-equivalent-working-group/ [Accessed 14.11.2023]

2.1.3 Wales

The Well-being of Future Generations (Wales) Act 2015 recognised that, in order to prevent persistent issues such as poverty, health inequalities and climate change, it was essential to consider the long-term implications of decisions. By planning for future generations, it would be possible to create a cohesive, prosperous and resilient Wales that is more equitable and healthier, enjoys a vibrant culture in which the Welsh language can thrive and is recognised as globally responsible.

The Environment (Wales) Act 2016 had enshrined in law the requirement to reduce net Welsh emissions by 80%of the baseline by 2050 and the requirement to determine interim emissions targets to reflect the success of implemented measures.

In response to the IPCC Special Report on Global Warming of 1.5°C - October 2018, Wales became the first nation to declare a Climate Emergency in April 2019. Accordingly, 2020-2030 was identified as a decade of action: more progress is required within these ten years than was achieved in the last thirty. Estimates showed that from 2020, greenhouse gas emissions would need to decline by 7.6% every year to 2030 to limit global warming to 1.5°C. Overall, emissions in Wales have fallen by 25% since 1990; however, dramatic reductions will be needed in the next decade, with Welsh Government targeting a 45% reduction by 2030.

Future Wales: The National Plan 2040 (2021) positions the planning system to deliver a prosperous and fairer Wales by normalising efficient use of resources to achieve sustainable lifestyles. It identifies the need for urgent action on carbon emissions with planning mechanisms geared toward helping Wales lead the way in delivering a competitive, sustainable decarbonised society. Decarbonisation commitments and renewable energy targets are promoted as opportunities to build a more resilient and equitable low-carbon economy: however, Net Zero targets are not enshrined in any of the 36 policies.

Most national carbon emission reduction strategies and plans, such as Welsh Government's Net Zero Wales Carbon Budget 2 (2021-2025), recognise that new build homes need to be energy efficient, use non-fossil fuelled energy sources and systems of operation. Buildings are responsible for almost half of the UK's carbon emissions, half of water consumption and about a quarter of all raw materials used in the economy, therefore reducing the impact of new development through planning policy can contribute towards sharp carbon reductions.

Planning Policy Wales Edition 11 (2021) incorporates 'The Energy Hierarchy for Planning' as a direct response to this analysis, mandating the reduction of energy demand as the highest priority for development. This clearly outlines Welsh Government's target of securing zero carbon buildings and the responsibility of the planning system to support development with high energy performance that supports decarbonisation, tackles the causes of the climate emergency and adapts to current and future effects of climate change.

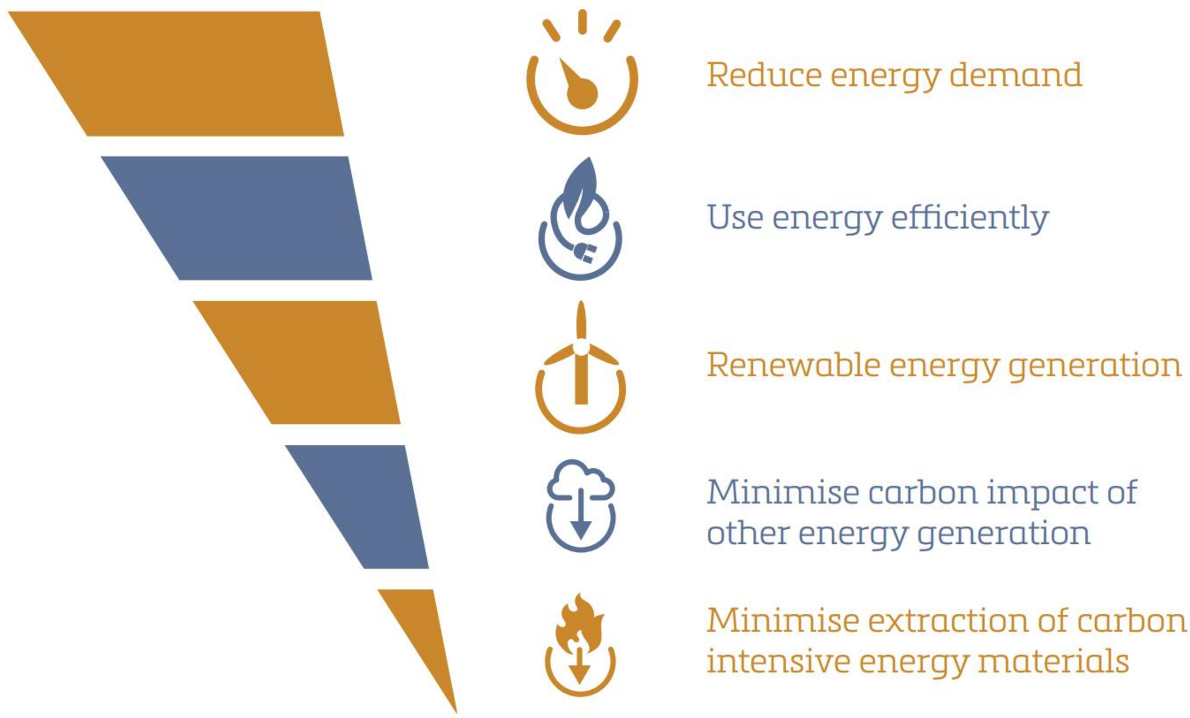

Fig. 1: The Energy Hierarchy for Planning[11]

For local and regional authorities, PPW11 suggests adopting an active leadership role with clearly established visions for decarbonisation. It also suggests Major Developments might require an Energy Report to outline how policy objectives could be successfully achieved. While recommending the impacts of both operational and embodied carbon emissions are given due consideration, policy currently leaves the assessment metrics and methodologies at the discretion of local authorities.

Approved Document L (Wales) Volume 1 - Dwellings and 2 - Buildings other than dwellings - Conservation of fuel and power 2022 align with the policy objectives of reducing emissions, mandating reductions of 31% for dwellings and 27% for non-domestic builds. Consultation documents for the 2025 Building Regulations suggest a 75% reduction in operational carbon emissions beyond 2014 standards: at present there are no details on whether embodied carbon will be assessed or regulated.

[11] Welsh Government (2021) Planning Policy Wales Edition 11 [online]. Cardiff: Welsh Government. Available from: www.gov.wales/planning-policy-wales [Accessed 16.10.2023]. Page 90.

Section 3: Net Zero Policy - Local Authority

3.1 Adopted

Since the IPCC Special Report on Global Warming of 1.5°C - October 2018, over 300 local authorities throughout England and Wales have declared a climate emergency[12]. Many are in the process of developing new policies to reduce carbon emissions, mitigate the impacts of anthropogenic climate change and build resilience into their communities.

While carbon reduction targets have been in place for years at a national level - primarily applied through Building Regulations and assessed via SAP methodology - it is only very recently that local authorities have adopted policies to explicitly target decarbonisation. This reflects an evolving understanding of the severity and urgency of the climate crisis and perceived inaction by government and uncertainty in satisfactorily addressing the issue.

Despite the clear wording of the Planning and Energy Act 2008, local authorities had previously been reluctant to implement energy performance targets with the perceived cause being a Written Ministerial Statement dating from 2015[13] that thwarted West Oxfordshire's attempt to mandate performance standards at Salt Cross Garden Village[14].

A Ministerial letter of confirmation in 2021 clarified:

> " *Local planning authorities have the power to set local energy efficiency standards through the Planning and Energy Act 2008. In January 2021, [the government] clarified in the Future Homes Standard consultation response that in the immediate term [the government] will not amend the Planning and Energy Act 2008, which means that local authorities still retain these powers.*"[15]

The National Model Design Code (2021) now requires local authorities to outline Net Zero targets within emerging design code and design guides.

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[12] Local Government Association (07 June 2023) Councils sound alarm on local climate threats. Available from: www.local.gov.uk/about/news/councils-sound-alarm-local-climate-threats#:~:text=Over%20300%20councils%20have%20declared,public%20health%2C%20and%20social%20care. [Accessed 14.11.2023].

[13] Secretary of State for Communities and Local Government, (2015) Planning Update [online]. London: The Stationery Office. (UIN HCWS488). Available from: questions-statements.parliament.uk/written-statements/detail/2015-03-25/HCWS488 [Accessed 13.11.2023].

[14] Donnelly, M., (2022) Planning Resource: Inspectors back 2,200-home garden village plan but block 'unjustified' net zero development policy. Available from: www.planningresource.co.uk/article/1791638/inspectors-back-2200-home-garden-village-plan-block-unjustified-net-zero-development-policy [Accessed 15.11.2023]

[15] Pincher, C., (2021) Rt Hon Christopher Pincher MP Minister of State for Housing in reply to Cllr Richard Millard of East Hampshire District Council, 24th January. [Letter]. Available from: 220124 response - Minister of State for Housing.pdf (dropbox.com) [Accessed 13.11.2023].

Local authorities have taken different approaches to implementing Net Zero policies. The following have, within their adopted Local Development Plans or Supplementary Planning Documents/ Guidance, been identified as incorporating Net Zero emission targets and/ or mandated targets for operational and embodied energy/ emissions substantially beyond basic levels of compliance with building control.

Local Authority	Policy Document	Date
Bath and North East Somerset	Core Strategy and Placemaking Plan incorporating the Local Plan Partial Update	2023 (Jan.)
Central Lincolnshire	Local Plan	2023 (Apr.)
Cornwall Council	Climate Emergency Development Plan Document	2023 (Feb.)
Glasgow	SG5: Resource Management	2017 (Feb.)
Lake District National Park	Design Code: Sustainable Design SPD	2023 (Sep.)

How each local authority has implemented Net Zero policies is explored within 3.1.1 Bath & North East Somerset, 3.1.2 Central Lincolnshire, 3.1.3 Cornwall, 3.1.4 Glasgow and 3.1.5 Lake District National Park. These sections of the review will present the quantitative targets and thresholds applied: the below summarises the relevant policies.

<table>
<tr><th>Local Authority</th><th>Operational Emissions</th><th>Embodied Emissions</th></tr>
<tr><td rowspan="2">Bath and North East Somerset</td><td>SCR6: Sustainable Construction Policy for New Build Residential Development</td><td rowspan="2">SCR8: Embodied Carbon</td></tr>
<tr><td>SCR7: Sustainable Construction Policy for New Build Non-Residential Buildings</td></tr>
<tr><td rowspan="2">Central Lincolnshire</td><td>S7: Reducing Energy Consumption - Residential Development</td><td rowspan="2">S11: Embodied Carbon</td></tr>
<tr><td>S8: Reducing Energy Consumption - Non-Residential Buildings</td></tr>
<tr><td>Cornwall Council</td><td>SEC1: Sustainable Energy and Construction</td><td>N/A</td></tr>
<tr><td>Glasgow</td><td>Gold Level</td><td>N/A</td></tr>
<tr><td>Lake District National Park</td><td colspan="2">Code 2.99: Sustainable Design, Embodied Energy and Construction</td></tr>
</table>

Other local authorities have been identified that have adopted policy with less ambitious or specific targets and these are deliberately excluded from this discussion. While well-intentioned, less ambitious targets fail to achieve Net Zero; when quantitative metrics and/or suitable assessment methodologies are not identified the policies fail to provide clarity to Council Officers or developers as to what is required to demonstrate compliance.

The author acknowledges that, while extensive, not every local authority was researched in the course of this work and it cannot therefore be considered exhaustive: other local authorities may have adopted or be developing similar policy that has not been identified.

3.1.1 Bath & North East Somerset

B&NES were the first local authority to adopt explicit Net Zero strategies, citing uncertainties surrounding the Future Homes Standard as a primary motivation[16] within its Core Strategy and Placemaking Plan incorporating the Local Plan Partial Update (2023).

SCR6: Sustainable Construction Policy for New Build Residential Development mandates targets of:

- Space heating target of 30 kWh/m²/yr;
- Total energy use less than 40 kWh/m²/yr;
- Renewable energy generation equal or greater than the annual electricity demand of the dwelling including all energy use with roof-mounted photovoltaics preferred;
- Connection to a low- or zero-carbon district heating network where available.

SCR7: Sustainable Construction Policy for New Build Non-Residential Buildings requires new build non-residential major development to achieve 100% reduction of regulated operational carbon emissions from Approved Document L (England) 2013.

An exclusion clause for major residential and non-residential development facilitates approvals where meeting renewable generation targets is unfeasible - due, for example, to the typology (i.e. apartments) - and in such scenarios mandates that renewable energy generation must be maximised and the residual on-site renewable generation offset by a financial contribution paid to the Council.

SCR8: Embodied Carbon requires developments exceeding 50 dwelling units or 5000m² commercial floor space to be supported by embodied carbon assessment demonstrating the substructure, superstructure and finishes do not exceed 900 $kgCO_2e/m^2$.

These policies establish clear quantitative thresholds for compliance. B&NES explicitly state that energy use was selected as the assessment metric because it is standalone and does not rely on a baseline derived from Approved Document L, therefore won't require updating with revisions to AD: L, and because energy metrics are considered more technically robust and designed to lead to better building outcomes with an improved focus on fabric[17].

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[16] Bath and North East Somerset Council (2023) Bath and North East Somerset Local Plan: Core Strategy and Placemaking Plan incorporating the Local Plan Partial Update: Volume 1 District-wide Strategy and Policies [online]. Bath: Bath and North East Somerset Council. Available from: beta.bathnes.gov.uk/policy-and-documents-library/development-plan-core-strategy-placemaking-plan-and-local-plan-partial [Accessed 06.11.2023]. Page 61.
[17] *Ibid.*, Page 61.

Since adoption in January the University of Bath in partnership with B&NES Council, Chapter2 Architects and the South West Net Zero Hub have compiled a report[18] assessing industry reaction to these new policies. Key findings were:

- 54% of eligible planning applications did not comply with the new operational energy policy, primarily due to a lack of awareness;
- Compliant applications can be lacking in transparency, hindering scrutiny;
- Providing sufficient renewable generation to match total energy use appears to be the most challenging policy requirement;
- Applicants expressed concern about cost impacts;
- Most applicants believed the policy will be effective in reducing operational and embodied carbon emissions and many signalled their support for the policy intention.

This provides valuable insight into the potential hurdles facing such policies in their current forms. However, as the first local authority to introduce such metrics, the lack of awareness and subsequent number of non-compliant applications should not be considered reflective of the wider industry response.

[18] Simaitis, J., Hawkins, W., Shea, A., Allen, S., Marsh, E., Phelps, P., Barnes, A. Daone, R., McCann, A., Bell, A. & Nikolaidou, E. (2023) Pioneering Net Zero Carbon Construction Policy in Bath & North East Somerset: Investigating the industry's response to the introduction of novel planning policies [online]. Bath: University of Bath. Available from: doi.org/10.15125/BATHRO-29738880 [Accessed 13.11.2023]

3.1.2 Central Lincolnshire

Central Lincolnshire acknowledge existing buildings are responsible for 43% of greenhouse gas emissions within the locale[19]. Like B&NES, they also cite the uncertainties surrounding the robustness and timescales for implementation of the Future Homes Standard[20] in their reasoning for developing Net Zero policy within the Central Lincolnshire Local Plan (2023).

Policy S7: Reducing Energy Consumption - Residential Development mandates Energy Statements accompany all new residential development to establish compliance with the mandated targets of:

- Renewable energy generation equal or greater than the annual electricity demand of the property including all energy use;
- Space heating target of 15-20 kWh/m²/yr;
- Site average total energy demand of 35 kWh/m²/yr and no dwelling unit to exceed 60 kWh/m²/yr irrespective of on-site renewable energy production.

Policy S8: Reducing Energy Consumption - Non-Residential Buildings requires Energy Statements for all new non-residential development to demonstrate:

- Renewable energy generation: equal or greater than the annual electricity demand of the property including all energy use;
- Space heating target of 15-20 kWh/m²/yr;
- Site average total energy demand of 70 kWh/m²/yr and no unit to exceed 90 kWh/m²/yr irrespective of on-site renewable energy production.

In both instances this must be calculated using a methodology proven to accurately predict building's actual energy performance and captured in the Energy Statements with positive weighting where it can be demonstrated there is a deliverable commitment to post-occupancy evaluation and ongoing monitoring of actual building energy use. Certification to the Passivhaus standards is also considered a route to demonstrating compliance.

Exclusion clauses are included to facilitate development contrary to these measures should it be demonstrated that compliance is unfeasible due to extraordinary site constraints.

Policy S11: Embodied Carbon has a presumption against demolition and requires developers to evidence the unsuitability of a building for refurbishment if demolition is proposed. Major

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[19] Central Lincolnshire Joint Strategic Planning Committee (2023) Central Lincolnshire Local Plan [online]. Lincoln: Central Lincolnshire Joint Strategic Planning Committee. Available from: www.lincoln.gov.uk/downloads/file/1423/central-lincolnshire-local-plan-2023 [Accessed 6.11.2023]. Page 29.

[20] *Ibid.,* Page 30.

development proposals should identify what opportunities to lower embodied carbon have been considered and what is proposed to be taken forward on the project.

The operational emission policies establish clear quantitative thresholds for compliance with exclusion clauses available should they be necessary. Embodied carbon remains qualitative for the moment with no clear metrics or thresholds applied: however, Central Lincolnshire advises that it expects to publish further guidance prior to 1 January 2025.

3.1.3 Cornwall

Cornwall Council introduced the Climate Emergency Development Plan Document (2023) to address the urgency of the climate crisis. This sets out the requirement for all new development proposals to align with the energy hierarchy and improve fabric standards, energy efficiency and minimise space heating demand before installing renewable energy and then offset residual energy if required: fabric first measures to reduce energy demand must be prioritised. It recognises this is the most sustainable approach that can also contribute to addressing fuel poverty and improving social equity[21].

SEC1: Sustainable Energy and Construction requires all new build residential development to target zero operational emissions and low embodied carbon by mandating targets of:

- Space heating target of 30 kWh/m²/yr;
- Total energy use less than 40 kWh/m²/yr;
- Renewable energy generation to match the annual electricity demand of the dwelling including all energy use with roof-mounted photovoltaics preferred.

An exclusion clause facilitates approvals where meeting renewable generation targets is unfeasible - due, for example, to the typology (i.e. apartments) - or unviable and in such scenarios mandates that renewable energy generation must be maximised and/ or connection to a low carbon district energy network sought. Once these options have been exhausted, residual on-site renewable generation is to be offset by a financial contribution paid to the Council.

New build non-residential major development (floor space exceeding 1000m²) is to achieve BREEAM 'Excellent' or an equivalent or better methodology.

Where economic viability or technical constraints prevent policy compliance, developments must prioritise fabric-first strategies to target space heating and total energy consumption thresholds. Renewable energy generation must then be maximised and/ or connection to a low carbon district energy network sought: finally, residual on-site renewable generation is to be offset by a financial contribution paid to the Council.

The same policy requires all development to minimise use of materials and the creation of waste, promoting opportunities for a circular economy.

[21] Cornwall Council (2023) Climate Emergency Development Plan Document [online]. Truro: Cornwall Council. Available from: www.cornwall.gov.uk/planning-and-building-control/planning-policy/adopted-plans/climate-emergency-development-plan-document/ [Accessed 06.11.2023]. Page 37.

By defining quantitative operational energy targets for residential development, Cornwall Council facilitate a straightforward route to assessing compliance for Council Officers and demonstrating compliance for developers. Major non-residential development has slightly more flexibility with BREAAM 'Excellent' or an "equivalent or better methodology" but also introduces uncertainty as to what could be considered an equivalent or better methodology and what would then be required to evidence compliance. Embodied carbon emissions are only addressed qualitatively with no clear metrics or thresholds established.

3.1.4 Glasgow

Glasgow proposes Net Zero options through SG5: Resource Management (2017). This predates other adopted policy by six years, supporting Glasgow City Development Plan (2017), but it is just one of three available options to residential development.

Alternative Gold Level Options: Domestic		
Option 1 Gold Hybrid	Option 2 Nearly Zero Emissions	Option 3 Net-Zero Carbon
Achieve Gold Aspect 1 along with Silver Active Level Aspects 2-8 inclusive	Achieve Passivhaus energy performance requirements with Gold Level Aspect 1 and Silver Active Level Aspects 4-8 inclusive	Achieve Platinum Level Aspect 1 and Silver Active Level Aspects 2-8 inclusive
All are required to include a minimum 20% carbon dioxide emission abatement through the use of low and zero carbon generating technologies **except** certified Passivhaus developments which are exempt		

Platinum, Gold and Silver targets defined by the Technical Handbook - Domestic (2017):

Platinum Level Aspect 1 requires CO_2 emissions 100% lower than Target Emission Rate (TER) to 2010 standards.

Gold Level Aspect 1 requires CO_2 emissions 27% lower than TER to 2015 standards.

Silver Active Level Aspect 2 requires:

- Space heating demand target of 40 kWh/m²/yr for houses;
- Space heating demand target of 30 kWh/m²/yr for flats or maisonettes.

Silver Active Level Aspect 3 requires at least 5% of the domestic building's annual energy demand for water heating to be from heat recovery and/ or renewable sources with little or no associated fuel costs that are allocated for water heating.

Silver Active Level Aspects 4-8 are not concerned with operational or embodied carbon.

Platinum, Gold and Silver targets defined by the Technical Handbook - Domestic (2023):

Platinum Level Aspect 1 requires CO_2 emissions 100% lower than TER to 2010 standards.

Gold Level Aspect 1 requires CO_2 emissions 46% lower than TER to 2010 standards.

Silver Active Level Aspects 2 and 3 are unchanged from the above and Silver Active Level Aspects 4-8 remain unconcerned with operational or embodied carbon.

Passivhaus energy performance requires:

- Space heating demand target of 15 $kWh/m^2/yr$ or heat load of 10 W/m^2.

This must be framed within the context of all new residential development required to achieve the Scottish equivalent of the Passivhaus Standard from 2025.

Non-domestic development is required to meet Gold Level Aspect 1 plus the required 20% carbon dioxide emission abatement through the use of low and zero carbon generating technologies. Compliance is to be demonstrated within a Statement of Energy that is then carried into a suspensive planning condition verified by Building Control through the Building Warrant process.

Only Option 3 would provide buildings with Net Zero operational emissions but the number of available routes to compliance appears to unnecessarily complicate matters. While all three routes are well-defined, by providing multiple options the likelihood is that the majority of development will adopt the option resulting in the lowest build cost rather than aspiring to best practice. Embodied carbon is not addressed.

3.1.5 Lake District National Park

Lake District National Park applies Net Zero policies through Design Code: Sustainable Design SPD (2023). This supports Living Lakes, Your Local Plan: Lake District National Park Local Plan 2020-2035 (2021).

Code 2.99: Sustainable Design, Embodied Energy and Construction requires all new build residential development to (in order of priority):

- Repair, pe-purpose and re-use existing buildings, structures, boundary features and infrastructure in order to capture their embodied carbon;
- Re-use, strengthen or introduce landscape features that will improve the building's energy efficiency by improving its microclimate;
- Use locally-sourced and non-toxic building materials with low embodied carbon that can be recycled or repurposed at the end of the building's life;
- A 'whole house' approach to energy efficiency that considers levels of insulation; orientation; airtightness; natural ventilation and achieving comfortable conditions in periods of warmer and drier weather;
- Design in anticipation of future adaptation;
- Include on-site renewable energy generation that can be easily altered or upgraded;
- Anticipate the need for landscaping, roofing, rainwater goods, etc. to be resilient and capable of dealing with more extreme weather events.

Additional information is then supplied via diagrams of embodied energy (materials and form factor), energy efficiency as impacted by orientation, sustainable design principles and renewable energy placement.

The Energy Hierarchy requires all new development to have a Life Cycle Assessment completed at the design stage and comply with clearly defined operational and embodied thresholds that align with the LETI guidance:

- Energy Use Intensity target of 35 $kWh/m^2/yr$ (ex. renewable energy contribution);
- Space heating demand target of 15 $kWh/m^2/yr$;
- Embodied carbon target of <500 $kgCO_2e/m^2$.

By defining clear quantitative operational and embodied energy targets for residential development the Lake District National Park facilitates a straightforward route to assessing compliance for Council Officers and demonstrating compliance for developers.

3.2 Emerging

The following table summarises proposed policies by local authorities within emerging plans that incorporate Net Zero emission targets or mandated operational and embodied energy/ emissions thresholds substantially beyond nationally mandated standards.

Local Authority	Operational Emissions	Embodied Emissions
Bristol	NZC1: Climate Change, Sustainable Design and Construction	
	NZC2: Net Zero Carbon Development - Operational Carbon	NZC3: Embodied Carbon, Materials and Waste
Enfield	SE4: Reducing Energy Demand	SE3: Whole-life Carbon and Circular Economy
	SE5: Greenhouse Gas Emissions and Low Carbon Energy Supply	
Essex	NZ1: Net Zero Carbon Development (in Operation)	NZ2: Net Zero Carbon Development - Embodied Carbon
Merton	CC2.2 Minimising Greenhouse Gas Emissions	CC2.5 Minimising Waste and Promoting a Circular Economy
	CC2.3 Minimising Energy Use	
Newham	CE2: Zero Carbon Development	CE3: Embodied Carbon
North Somerset	DP6: Net zero construction	
Oxford	R1: Net Zero Buildings in Operation	R2: Embodied Carbon in the Construction Process
Warwick	NZC1: Achieving Net Zero Carbon Development	NZC3: Embodied Carbon
	NZC2(A): Making Buildings Energy Efficient	
	NZC2(B): Zero or low Carbon Energy Sources and Zero Carbon Ready Technology	
	NZC2(C): Carbon Offsetting	
Wiltshire	Policy 85: Sustainable Construction and Low Carbon Energy	87: Embodied Carbon

The proposed quantitative thresholds for these policies are explored within 3.2.1 Bristol, 3.2.2 Enfield, 3.2.3 Essex, 3.2.4 Merton, 3.2.5 Newham, 3.2.6 North Somerset, 3.2.7 Oxford, 3.2.8 Warwick and 3.2.9 Wiltshire.

The author acknowledges that, while extensive, not every local authority was researched in the course of this work and it cannot therefore be considered exhaustive: other local authorities may have adopted or be developing similar policy that has not been identified.

3.2.1 Bristol

The Bristol Local Plan Review: Draft Policies and Development Allocations (2022) has been drafted to tackle the Climate Emergency and meet ambitious zero carbon reduction targets by 2030.

NZC1: Climate Change, Sustainable Design and Construction provides a broad overview of Bristol's ambition to respond to the climate crisis and directly references **NZC2** and **NZC3**. All new development is required to demonstrate adherence to policy through Sustainability Statements; major non-residential development is expected to achieve BREEAM Excellent and residential or mixed-use development comprising more than 100 residences will require a BREEAM Communities Excellent rating.

Adoption of quality assurance methods such as Passivhaus certification is supported.

NZC2: Net Zero Carbon Development - Operational Carbon will require all new development to target zero operational emissions and submit an Energy Statement demonstrating compliance with proposed targets of:

- Space heating target of 15 kWh/m²/yr;
- Energy use intensity of 35 kWh/m²/yr for new homes;
- Operational energy/ carbon consistent with BREEAM Excellent for major non-residential development;
- Renewable energy generation to match the annual electricity demand of the development including all energy use.

An exclusion clause facilitates approvals where meeting renewable generation targets is unfeasible - due, for example, to the typology (i.e. apartments) - or unviable and in such scenarios mandates that renewable energy generation must be maximised with a target of 105 kWh/m²fp/yr. Residual on-site renewable generation is to be either offset by a financial contribution to fund Council-approved renewable energy, low-carbon energy and energy efficiency schemes or agreeing acceptable directly linked or near-site provision.

Passivhaus Classic, Plus and Premium are all offered as alternative routes to compliance that remove the need to meet on-site generation targets or submit a full Energy Strategy.

Development should also, through the Energy Strategy, demonstrate proposals for smart and flexible technologies to reduce peak load and how the most sustainable heating and - only when all passive routes have been exhausted - cooling systems have been selected. Where available, development should prioritise connection to a classified heat network and thereafter employ renewable individual or communal heating systems: no fossil fuels.

Proposed development must address and minimise the performance gap between design aspiration and completed development by implementing a recognised quality regime.

NZC3: Embodied Carbon, Materials and Waste will require all new development to set out how embodied carbon has been minimised through the Sustainability Statement. Fixed building services using refrigerants must prioritise specification of the lowest GWP available and these refrigerants must be reflected within embodied carbon assessments.

The following quantitative targets are proposed for major development:

- Residential (4 storeys or fewer) < 625 $kgCO_2e/m^2$;
- Residential (5 storeys or greater) < 800 $kgCO_2e/m^2$;
- Non-residential schemes < 970 $kgCO_2e/m^2$.

An exclusion clause facilitates approvals where meeting these targets is unfeasible but a full justification must be provided as part of the embodied carbon assessment. Any shortfall will be offset by a financial contribution to fund Council-approved renewable energy, low-carbon energy and energy efficiency schemes.

3.2.2 Enfield

The Enfield Local Plan: Main issues and preferred approaches (2021) has been drafted to tackle the Climate Emergency and to set an exemplar precedent.

SE3: Whole-life carbon and circular economy will require all major development proposals to be accompanied by a Circular Economy Statement to:

- Prioritise reusing and retrofitting existing buildings;
- Minimise environmental impacts of materials;
- Design for durability and flexibility, demonstrating how the design and construction allows for disassembly and reused at the end of useful life;
- Evidence where the circular economy has been promoted;
- Demonstrate how circular economy principles have informed the design and implementation of energy, heating, cooling, water and waste infrastructure.

The following quantitative targets are proposed for major development, establishing clear sequential improvements through the lifecycle of the plan. These must be calculated by a nationally recognised whole life carbon assessment and proposals should demonstrate the actions taken to reduce life-cycle carbon emissions in line with the below.

	1^{st} January 2023 (or Local Plan adopted)	1^{st} January 2025	1^{st} January 2030
Domestic	< 600 $kgCO_2e/m^2$	< 450 $kgCO_2e/m^2$	< 300 $kgCO_2e/m^2$
Non-domestic	< 800 $kgCO_2e/m^2$	< 650 $kgCO_2e/m^2$	< 500 $kgCO_2e/m^2$

SE4: Reducing energy demand will require all developments resulting in the creation of one or more dwellings or more than 500m² non-residential GIA to achieve the quantitative space heating and operational energy use (energy use intensity: EUI) targets in the table below.

	1^{st} January 2023 (or Local Plan adopted)	1^{st} January 2025	1^{st} January 2030
Space heating	30 $kWh/m^2/yr$	20 $kWh/m^2/yr$	15 $kWh/m^2/yr$
EUI (domestic)	105 $kWh/m^2/yr$	70 $kWh/m^2/yr$	35 $kWh/m^2/yr$
EUI (non-domestic)	170 $kWh/m^2/yr$	110 $kWh/m^2/yr$	55 $kWh/m^2/yr$

Passivhaus equivalent certification will also be considered to demonstrate compliance.

Major developments resulting in the creation of ten or more dwellings or more than 1,000m² non-residential GIA will be required to evaluate operational energy use using realistic information on the intended use, occupancy and operation of the building to minimise the performance gap. This will be demonstrated through compliance with the above targets using a methodology such as PHPP or CIBSE TM54 Operational Energy.

There is an additional requirement for major developments to monitor energy usage in the first 5 years of operation for submission to the local authority for their scrutiny.

SE5: Greenhouse gas emissions and low carbon energy supply will require all developments resulting in the creation of one or more dwellings or more than 500m² non-residential GIA to provide an Energy Statement to demonstrate how emissions savings have been maximised at each stage of the energy hierarchy and achieve carbon reductions as outlined below.

All major residential developments resulting in the creation of ten or more dwellings and non-residential development of more than 500m² GIA will be required to be Net Zero. A cash in lieu contribution to meet Net Zero will be acceptable only where it has been clearly demonstrated that no further savings are feasible on site due to constraints or limitations.

	Minimum on-site total reduction in CO_2	Residual emissions carbon offset fund contribution
Major residential development of ten or more dwellings	Net-zero with minimum 45% on-site reduction	Tiered offset
Minor new build residential development of one or more dwellings	45% minimum on-site reduction with	£1,500 flat fee per dwelling
Minor residential change of use and conversions resulting in the creation of one or more dwellings	35% minimum on-site reduction with	£1,500 flat fee per dwelling
Non-residential development > 500m² GIA	Net-zero with minimum 45% on-site reduction	Tiered offset

All new developments resulting in the creation of one or more dwellings or 500m² or more non-residential GIA will be required to install low carbon heating and hot water. New developments should not be connected to the gas grid, except for in exceptional circumstances, and there should be no on-site combustion of fossil fuels.

If connection to a decentralised energy network is not possible, large-scale major developments proposals comprising 200 or more dwellings or 10,000m² or more non-residential GIA will be expected to consider the integration of new energy networks in the development with consideration for future connection to the boroughs heat network. This consideration shall form part of the development proposals and take into account site characteristics and the existing cooling, heat and power demands on adjacent sites where readily available.

All developments will be required to install on-site renewable energy generation equating to a minimum 120 kWh/m²fp/yr unless it can be clearly demonstrated that this is not viable.

3.2.3 Essex

The Planning Policy Position for Net Zero Carbon Homes and Buildings in Greater Essex (2023) has been prepared by the Climate and Planning Unit in response to government's inaction on the Climate Emergency.

NZ1: Net Zero Carbon Development (in Operation) will require all new build development resulting in the creation of one or more dwellings or 100m² or more non-residential area to be Net Zero in operation.

Defined space heating targets are:

- 15 kWh/m²/yr for all residential and non-residential typologies except bungalows;
- 20 kWh/m²/yr for bungalows.

All buildings must be fossil-fuel free in operation with no connections to the gas grid. No fossil fuels must be used on-site for heating, hot water and cooking.

Defined energy use intensity targets are:

- 35 kWh/m²/yr for Class C3 and C4 residences;
- 65 kWh/m²/yr for schools;
- 70 kWh/m²/yr for offices;
- 35 kWh/m²/yr for light industrial;
- All other use classes must report EUI.

Renewable energy generation to deliver the greater of: matching the annual electricity demand of the development including all energy use or generating at least 80 kWh/m²fp/yr for all building types and at least 120 kWh/m²fp/yr for industrial.

An exclusion clause facilitates approvals where meeting renewable generation targets is unfeasible - due, for example, to the typology (i.e. apartments) - or unviable and in such scenarios mandates that renewable energy generation must be maximised. Residual on-site renewable generation is to be either offset by a financial contribution to fund Council-approved renewable energy schemes in the plan area.

All developments must submit as-built performance information at completion and prior to occupation. In-use energy monitoring is required on a minimum of 10% of dwellings for development proposals of 100 dwellings or more for the first 5 years of operation.

Proposals that are built and certified to the Passivhaus Classic or higher Passivhaus standard are deemed to have met space heating and energy use intensity targets. Developments that achieve these standards must still be fossil fuel free, demonstrate appropriate renewable energy generation and provide in-use monitoring data.

NZ2: Net Zero Carbon Development - Embodied Carbon will require all new build development resulting in the creation of one hundred or more dwellings or 5,000m² or more non-residential area to submit whole life cycle carbon assessments.

The following quantitative targets are proposed for development meeting these criteria:

- Upfront carbon - residential < 500 $kgCO_2e/m^2$;
- Upfront carbon - non-residential < 600 $kgCO_2e/m^2$;
- Lifecycle carbon - residential < 800 $kgCO_2e/m^2$;
- Lifecycle carbon - non-residential < 970 $kgCO_2e/m^2$.

3.2.4 Merton

The Merton Local Plan: Publication Stage 3 (2021) aims to achieve net-zero carbon by 2050 by reducing greenhouse gas emissions and increasing local resilience to the impacts of a changing climate through sustainable design.

CC2.2 Minimising Greenhouse Gas Emissions establishes the general principles to be adopted in alignment with The London Plan (2021). These are to:

- Be lean: use less energy and manage demand during operation;
- Be clean: exploit local energy resources (such as secondary heat) and supply energy efficiently and cleanly;
- Be green: maximise opportunities for renewable energy by producing, storing and using renewable energy on-site;
- Be seen: monitor, verify and report on energy performance.

All new developments resulting in the creation of one or more dwellings or 500m² or more non-residential GIA will be required to provide an Energy Statement to demonstrate how emissions savings have been maximised at each stage of the energy hierarchy and achieve carbon reductions as outlined below.

Development Type	Minimum on-site total CO_2 reduction
Major residential development of ten or more dwellings	60%
Minor new build residential development of one or more dwellings	60%
Minor residential change of use and conversions resulting in the creation of one or more dwellings	35%
Non-residential development > 500m² GIA	50%

CC2.3 Minimising Energy Use will require all developments resulting in the creation of one or more dwellings or more than 500m² non-residential GIA to achieve the space heating targets in the table below.

	31st December 2022	1st January 2023 - 31st December 2024	1st January 2025
Blocks of flats and mid-terrace houses	43 kWh/m²/yr	39 kWh/m²/yr	15 kWh/m²/yr
Semi-detached and detached houses	52 kWh/m²/yr	46 kWh/m²/yr	20 kWh/m²/yr
Non-residential	15% uplift on BR	15% uplift on BR	15 kWh/m²/yr

There is an additional requirement for major developments to monitor energy usage in the first 5 years of operation for submission to the local authority. Discussion highlights:

" It is widely accepted that there is a significant performance gap between the energy use and carbon emissions estimated at design stage and the actual in-use performance of buildings using the current Building Regulations Part L methodology, and that this needs to be addressed in order to genuinely make our buildings net-zero carbon. The Part L methodology uses carbon emissions as the main performance metric which is dependent on the carbon factor of the electricity grid and does not necessarily reflect good operational performance. The UK Passivhaus Trust found that new build houses have an average performance gap of 40% between the actual overall energy use compared to the EPC modelling carried out at design stage which means that buildings are emitting significantly more carbon than predicted using the SAP methodology."

[…]

" In addition, current Building Regulations (2013) do not address unregulated emissions associated with cooking, white goods and other equipment which can represent up to 50% of a building's operational emissions. Operational performance of buildings therefore cannot be verified using the Part L methodology. The CCC has highlighted the importance of improving building performance monitoring and focussing on 'as built' performance in order to close this performance gap which could deliver £70-260 in annual bill savings per household."

[…]

" In order to improve our understanding of energy demand and drive more energy efficient design of buildings, Merton Council requires all developments resulting in the creation of 1 or more dwellings or 500sqm or more non-residential GIA to determine their anticipated EUI, at planning and pre-occupation stage. Major schemes will need to calculate the anticipated regulated and unregulated energy demand, and combined EUI, using the CIBSE TM54 methodology, Passive House Planning Package (PHPP) methodology or equivalent, or successor methodologies. Minor residential schemes resulting in the creation of one or more dwellings will need to estimate the expected regulated and unregulated energy demand, and combined EUI, using the Part L methodology or equivalent, or successor methodologies."

[…]

"Developments are also encouraged to adopt recognised and successful fabric first approaches such as Passivhaus which is seen as the most stringent low 'energy in use' standard and is consistent with LETI's Climate Emergency Design Guide. This standard also relies on a more accurate energy demand assessment methodology using the Passive House Planning Package (PHPP)."[22]

[22] Merton Council (2021) Merton Local Plan: Publication Stage 3 [online]. London: Merton Council. Available from: www.merton.gov.uk/planning-and-buildings/planning/local-plan/newlocalplan/climate-change [Accessed 15.11.2023]. Pages 54-56.

CC2.5 Minimising Waste and Promoting a Circular Economy will require all development to:

- Prioritise reusing and retrofitting existing buildings;
- Design for durability and flexibility, demonstrating how the design and construction allows for disassembly and reused at the end of useful life. Building shape and form should minimise embodied carbon and limit the need for repair and replacement;
- Ensure resource efficiency and reduce embodied carbon by sourcing and prioritising materials that can be easily maintained, repaired and renewed through the lifecycle of the development;
- Minimise the environmental impact of materials by specifying sustainably sourced, low impact and re-used or recycled materials.

All development resulting in the creation of thirty or more dwellings or 1000m^2 or more non-residential GIA, and all development proposing to demolish and rebuild a single dwelling, will be required to undertake a Whole Life-Cycle Carbon assessment proportionate to the scale of development and demonstrate whole lifecycle carbon savings are maximised.

3.2.5 Newham

The Newham Draft Local Plan (Regulation 18) (2022) has been drafted to tackle the Climate Emergency to meet commitments to be carbon neutral by 2030 and carbon zero by 2045.

CE2: Zero Carbon Development will require all new development to achieve space heating, energy use intensity and renewable generation targets to be Net Zero in operation.

Metric	Compliance Threshold
Space heating demand	• 20 kWh/m²/yr for dwellings and non-domestic ex. industrial buildings • 15 kWh/m²/yr for industrial buildings
Energy use intensity	• 35 kWh/m²/yr for dwellings and student accommodation • 55 kWh/m²/yr for offices, retail, higher education teaching facilities, GP surgeries and hotels • 65 kWh/m²/yr for schools • 100 kWh/m²/yr for leisure, warehouses and light industrial units (additional 20 kWh/m²/yr budget for units operating 24 hours a day)
On-site renewable generation	At least the predicted annual energy demand and: • 80 kWh/m²/yr per building footprint of all typologies ex. industrial • 120 kWh/m²/yr per building footprint of industrial buildings

There is an additional requirement for major developments to monitor energy usage in the first 5 years of operation for submission to the local authority. Discussion repeats:

> *" Part L energy assessment methodologies (e.g. Standard Assessment Procedure (SAP) for domestic buildings and National Calculation Methodology (NCM) for non-domestic buildings) are currently used to evidence the energy and carbon efforts for all planning applications and demonstrate their compliance with current policy requirements. However, it is important to note that these were developed only to check compliance with Building Regulations, not whether buildings comply with Net Zero Carbon buildings policies, and or the prediction of future energy use. Instead, this policy recommends use of Passive House Planning Package (PHPP) for new build residential schemes, as it has been shown to predict energy use much more accurately than SAP. Comparative SAP/ PHPP modelling undertaken on different typologies suggest that SAP underestimates space heating demand by more than 50 per cent."*[23]

CE3: Embodied Carbon requires all new major development to have a Whole Life Cycle Assessment to demonstrate compliance with:

- Embodied carbon target of <500 kgCO_2e/m².

[23] Newham Council (2022) Climate Emergency Development Plan Document [online]. London: Newham Council. Available from: www.newham.gov.uk/downloads/file/5486/newham-local-plan-december-2022-web-final [Accessed 15.11.2023]. Page 238.

3.2.6 North Somerset

The North Somerset Local Plan 2039: Pre-submission Plan (2023) has been developed in response to the declared climate emergency. Proposed policies aim to respond to an impending cultural transformation which reflects a more responsible attitude to climate change and the use of resources.

DP6: Net Zero Construction will require all new development to target zero operational emissions. Adherence to the energy hierarchy ensures building design prioritises energy reduction through highly energy efficient fabric measures, lighting, ventilation and orientation. Once energy demand is minimised and efficiency design measures in place, renewable energy technologies can then be used to meet residual energy demand.

All new development will be required to minimise embodied carbon in respect of both upfront (emissions associated with raw materials, transportation, manufacturing and construction) and whole life carbon. For development of more than 50 dwellings, or in excess of 5,000m² non-residential floorspace, proposals must be accompanied by an embodied carbon assessment which demonstrates upfront embodied carbon emissions do not exceed 900 $kgCO_2e/m^2$.

Additionally, retaining existing buildings is to be given preference to demolition. Retrofitting energy efficiency measures in existing buildings will be supported and significant weight given to the benefits of development resulting in considerable improvements to energy efficiency. All proposals must demonstrate high standards of insulation with the EnerPhit standard encouraged.

All new residential development must submit an Energy Statement demonstrating compliance with proposed targets of:

- No fossil fuels;
- Space heating demand of 15 kWh/m²/yr;
- Energy use intensity of 35 kWh/m²/yr;
- Renewable energy generation to match the annual electricity demand of the development including all energy use.

Passivhaus Plus is offered as an alternative means of demonstrating compliance.

All new non-residential development must submit an Energy Statement demonstrating compliance with proposed targets of:

- No fossil fuels;
- Energy use intensity minimised appropriate to the end use;

- Renewable energy generation is maximised, equivalent to at least the annual electricity demand of the development including all energy use;
- End users report actual energy use in operation for five years post-completion.

BREEAM Excellent is offered as an alternative means of demonstrating compliance with particular emphasis on achieving Outstanding level for energy use (Ene01). Other suitable alternatives may be allowed subject to prior agreement.

An exclusion clause facilitates approvals where meeting renewable generation targets on-site is technically unfeasible - due, for example, to the typology (i.e. apartments) - and in such scenarios mandates that renewable energy generation must be maximised with any residual generation met off-site.

The policy ends by reiterating that energy use intensity and space heating targets should be prioritised regardless of any district heating connection and all reasonable efforts made to meet these requirements prior to buildings connecting to a district heating network.

3.2.7 Oxford

The Oxford Local Plan 2040: Submission Draft (2023) has been developed in response to the declared climate emergency. Policies aim to prepare the city for a net zero carbon future and the commitment to be net zero city by 2040.

R1: Net Zero Buildings in Operation will require all new development to target zero operational emissions and submit an Energy and Carbon Statement demonstrating compliance with proposed targets of:

- Designing in accordance with the energy hierarchy;
- Energy use intensity of 35 kWh/m²/yr for residential;
- Energy use intensity of 70 kWh/m²/yr for non-residential;
- Space heating portion of EUI no greater than 20 kWh/m²/yr;
- No fossil fuels;
- Renewable energy generation to match the annual electricity demand of the development including all energy use;
- Specified approach for post-occupancy evaluation to ensure operational performance aligns with calculated predictions.

An exclusion clause facilitates approvals where meeting targets is unfeasible. In such scenarios, development proposals will have to demonstrate:

- Full details of where criterion cannot be met must be provided and justified with explanation of the reasonable attempts to meet it;
- Clarification that all other criteria are met or exceeded;
- The proposal is overall net zero carbon in operation, using no fossil fuels and with offsets employed as a last resort to achieve the standard.

All energy calculations required for this policy will need to be undertaken using an approved methodology. CIBSE TM54 is identified as the most appropriate methodology with the Energy and Carbon Technical Advice Note (TAN) expanding on this with additional guidance.

R2: Embodied Carbon in the Construction Process will require all development to:

- Re-use of existing buildings has been robustly explored and demonstrated to be unfeasible before resorting to demolition;
- Waste generation has been minimised and re-use and recycling of materials has been maximised in construction, including using any demolition materials;
- Selection of construction materials has been informed by the carbon footprint associated with their extraction and production (carbon footprint sought to be reduced wherever possible); prioritise using materials that sequester more carbon than is produced in making them where opportunities arise;

- How materials are transported to and processed on site has been informed by minimising the associated carbon emissions wherever possible;
- Design choices ensure buildings can be easily maintained, adapted and repurposed at the end of use/ life.

Proposals resulting in the creation of one hundred or more dwellings or 10,000m² or more non-residential GIA will need to provide the following additional justification within the Energy and Carbon Statement:

- Measurement of the total embodied carbon associated with the construction process using a recognised methodology;
- Details of actions taken to reduce this embodied carbon and the specific reductions that have been achieved through the design process

Where future updates to Building Regulations or other national policy mandate embodied carbon at a national level the Energy and Carbon Statement should instead demonstrate how embodied carbon is being addressed in the context of that national legislation.

3.2.8 Warwick

Warwick District Council's Net Zero Carbon: Development Plan Document (2022) is a result of the Climate Emergency Action Programme (CEAP) and resultant Climate Change Action Programme (CCAP) to get Warwick District to as close as possible to Net Zero by 2030.

NZC1: Achieving Net Zero Carbon Development will require all new development resulting in the creation of one or more dwellings or 1,000m² or more non-residential, residential institution or hotel GIA to target zero operational emissions and submit an Energy Statement demonstrating compliance with:

- 63% reduction in carbon emissions achieved on-site for new dwellings;
- 35% reduction in carbon emissions achieved on-site for non-residential buildings, hotels and residential institutions;
- Compliance with **NZC2(A)** and **NZC2(B)**;
- Any residual operational regulated carbon emissions (within 30 year period) to be offset to zero in accordance with **NZC2(C)** where it can be demonstrated that on-site measures and near-site renewables are unfeasible or unviable.

Passivhaus Classic, Plus and Premium are all offered as alternative routes to compliance that remove the need to meet on-site generation targets or submit a full Energy Strategy.

NZC2(A): Making Buildings Energy Efficient will require all new development resulting in the creation of one or more dwellings to demonstrate 10% improvement on the Part L 2021 Target for Fabric Energy Efficiency. New developments of 1,000m² or more of new non-residential, hotel or residential institution GIA will be expected to demonstrate 19% reduction in CO_2e emissions compared to Part L 2013 through energy efficiency measures.

NZC2(B): Zero or Low Carbon Energy Sources and Zero Carbon Ready Technology will require all new development resulting in the creation of one or more dwellings or 1,000m² or more non-residential, residential institution or hotel GIA to demonstrate that additional renewable, zero and low carbon energy technologies have been provided on-site to achieve the carbon reductions required by **NZC1** and achieve on-site net zero operational carbon.

Exclusion clauses facilitate approvals where compliance is not feasible or viable. In this scenario, proposals must demonstrate through the Energy Statement that carbon reductions to the greatest extent feasible have been considered and incorporated through applying the energy hierarchy. In applying the energy hierarchy, proposals are expected to implement fabric energy efficiency and low carbon heating before incorporating renewable electricity generation and then offsetting.

NZC2(C): Carbon Offsetting will require all new development resulting in the creation of one or more dwellings or 1,000m² or more non-residential, residential institution or hotel GIA that cannot achieve Net Zero to address residual carbon emissions by either a cash in lieu contribution to the District Council's carbon offsetting fund or, at the Council's discretion, a verified local off-site offsetting scheme.

NZC3: Embodied Carbon will require all major development to demonstrate in the Design or Energy Statement how embodied carbon has been reduced. Further, proposals for development of 50 or more new dwellings and/or 5,000sqm or more of new non-residential GIA should be accompanied by a whole-life assessment of the materials used.

3.2.9 Wiltshire

The Wiltshire Local Plan Pre-Submission 2020-2038 (Regulation 19) (2023) is designed to help mitigate and adapt to climate change by contributing to the delivery of sustainable development, helping ensure communities are resilient to the unavoidable consequences of climate change.

Policy 85: Sustainable Construction and Low Carbon Energy requires all new build residential development to target zero operational emissions and low embodied carbon by mandating targets of:

- Space heating target of 30 $kWh/m^2/yr$;
- Total energy use less than 40 $kWh/m^2/yr$;
- Renewable energy generation to match the annual electricity demand of the dwelling including all energy use with roof-mounted photovoltaics preferred;
- Connection to a district heating network where available.

Major non-residential development is to achieve BREEAM Excellent and Net Zero in operational emissions following the hierarchy of minimising energy use; connecting to a heat network where available; maximise opportunities for renewable generation.

An exclusion clause facilitates approvals where meeting renewable generation targets is unfeasible - due, for example, to the typology (i.e. apartments) - or unviable and in such scenarios mandates that renewable energy generation must be maximised. Once these options have been exhausted, residual on-site renewable generation is to be offset by developer contributions paid to the Council.

Policy 87: Embodied Carbon requires all new major residential and non-residential development to have a Whole Life Cycle Assessment to demonstrate compliance with:

- Embodied carbon target of $<900\ kgCO_2e/m^2$.

Section 4: Summary

4.1 Summary

The policies reviewed within this report demonstrate a wide range of ambitions. Most pertinent to developing an appropriate policy approach is identifying the most appropriate and technically robust metrics and methodologies for assessment.

Quantitative operational energy metrics establish clear thresholds for compliance that are considered technically robust and are designed to lead to better building outcomes with an improved focus on fabric. Baselines derived from Approved Document L inevitably fall out of step with revisions to the document and quickly fail to accurately reflect current regulations.

Heating demand is considered the most appropriate operational energy metric to ensure the prioritisation of a fabric first approach. Energy use intensity as a secondary metric motivates the specification of high efficiency heating and hot water systems.

Quantitative embodied energy metrics establish clear thresholds for compliance prior to the introduction of any legislated targets.

Incremental improvements to these standards through the lifecycle of the plan would enable Vale of Glamorgan Council to onboard the local supply chain at a relatively deliverable point and subsequently leverage increasing levels of building performance as the knowledge and skills within the local ecosystem improve.

Alternative routes to compliance - such as Passivhaus certification - should be considered.

Exclusion clauses should be considered to facilitate approvals where compliance is unfeasible or unviable and in such scenarios proposed development should adhere to the Energy Hierarchy with residual emissions offset by financial contributions as the last resort.

4.2 Policy Approach

Vale of Glamorgan policy, informed by the precedents discussed within this report, should seek to establish clear quantitative compliance thresholds and appropriate assessment methodologies. This section explores one potential way of structuring policies: an umbrella Net Zero policy supported by specific Operational Carbon and Embodied Carbon policies.

All are presented indicatively for discussion and development with Vale of Glamorgan with placeholder figures derived from previously discussed policies. All quantitative compliance thresholds would be informed by the outcome of Work Stage 2E - Technical Feasibility and Work Stage 3F - Cost Analysis.

Net Zero

*All new build development will be required to submit an **Energy and Carbon Statement** demonstrating compliance with operational and embodied carbon targets. All development proposals should follow the Energy and Development Hierarchies outlined below.*

Energy Hierarchy:

- *Reduce energy demand through passive measures including form, orientation and fabric;*
- *Use energy efficient mechanical and electrical systems, including heat pumps, heat recovery and LED lights;*
- *Maximise renewable energy especially through decentralised sources, including on-site generation and community-led initiatives.*

Development Hierarchy:

- *Prioritise reusing and retrofitting existing buildings;*
- *Design for durability and flexibility, demonstrating how the design and construction allows for disassembly and reused at the end of useful life. Building shape and form should minimise embodied carbon and limit the need for repair and replacement;*
- *Ensure resource efficiency and reduce embodied carbon by sourcing and prioritising materials that can be easily maintained, repaired and renewed through the lifecycle of the development;*
- *Minimise the environmental impact of materials by specifying sustainably sourced, low impact and re-used or recycled materials.*

__Operational Carbon__

The following quantitative targets are proposed for all development with sequential improvement through the lifecycle of the plan. These must be calculated by a nationally recognised energy assessment methodology (as defined within RICS: Whole life carbon assessment for the built environment 2nd edition (2023) or subsequent revisions) using realistic information on the intended use, occupancy and operation of the building to minimise the performance gap. Where national policy or legislation is introduced that exceeds these thresholds, the higher (i.e. less carbon intensive) target must be met.

	rLDP adoption to	01.01.2030 to	01.01.35 onwards
Space heating	30 kWh/m²/yr	15 kWh/m²/yr	
EUI domestic	40 kWh/m²/yr	35 kWh/m²/yr	
EUI non-domestic	160 kWh/m²/yr	110 kWh/m²/yr	55 kWh/m²/yr

Once space heating and EUI targets have been achieved, renewable energy generation equal or greater than the EUI should be targeted. Where meeting renewable generation targets is unfeasible - due, for example, to the typology (i.e. apartments) - or unviable then renewable energy generation must be maximised. Once options have been exhausted, residual on-site renewable generation is to be either offset by a financial contribution to fund Council-approved renewable energy, low-carbon energy and energy efficiency schemes or agreeing acceptable directly linked or near-site provision.

Passivhaus Classic or equivalent or better certification will be considered to demonstrate compliance with space heating targets.

Major developments will be required to monitor energy usage for the first 5 years of operation and submit to Vale of Glamorgan to ensure alignment with predicted usage.

Where available, all new development should seek to connect to a low- or zero-carbon district heating network.

Embodied Carbon

The following quantitative targets are proposed for all development with sequential improvement through the lifecycle of the plan. These must be calculated by a nationally recognised whole life carbon assessment methodology (as outlined within RICS: Whole life carbon assessment for the built environment 2nd edition (2023) or subsequent revisions) and proposals should demonstrate the actions taken to reduce life-cycle carbon emissions in line with the below. Where national policy or legislation is introduced that exceeds these thresholds, the higher (i.e. less carbon intensive) target must be met.

	rLDP adoption to	*01.01.2030 to*	*01.01.35 onwards*
Domestic	< 600 $kgCO_2e/m^2$	< 450 $kgCO_2e/m^2$	< 300 $kgCO_2e/m^2$
Non-domestic	< 800 $kgCO_2e/m^2$	< 600 $kgCO_2e/m^2$	< 400 $kgCO_2e/m^2$

If adherence with these targets is unfeasible a full justification must be provided as part of the embodied carbon assessment. Any shortfall will be offset by a financial contribution to fund Council-approved renewable energy, low-carbon energy and energy efficiency schemes.

4.3 Evidence Base

In addition to the summaries presented within this report and the excerpts of relevant policy supplied in the Appendix, the evidence base for each local authority is available to access via the following links.

Adopted	Emerging
B&NES	Bristol
Central Lincolnshire	Enfield
Cornwall	Essex
Lake District National Park	Merton
	Newham
	Oxford
	Warwick

Unit 2
Chapel Barns
Merthyr Mawr
Bridgend
CF32 0LS

T: 01656 656267
W: www.spring-consultancy.co.uk

Architecture
Low Energy Consultancy
Civil Engineering
Structural Engineering
Urban Design

Vale of Glamorgan Council

Net Zero Carbon Buildings Feasibility Study and Cost Assessment

Work Stage 2D

Methodologies

January 2024

Revision B

May 15th 2024

Architecture
Low Energy Consultancy
Civil Engineering
Structural Engineering
Urban Design

Contents

Section 1: Introduction

1.1 Introduction

Spring Design Consultancy Limited are appointed to assist Vale of Glamorgan Council in developing suitably evidenced Net Zero policy to guide, assess and determine applications for new-build residential and non-residential development within the emerging Replacement Local Development Plan 2021-2036.

This process has been divided into distinct work stages:

Work Stage 1 A - Policy Review
B - Policy Approach
C - Evidence Base

Work Stage 2 D - Methodologies
E - Technical Feasibility

Work Stage 3 F - Cost Analysis

Work Stage 4 G - Evidence
H - Cost Implications
I - Scrutiny Skillset

Work Stage 5 Examination

This report summarises the specifications informing Work Stage 2D - Methodologies.

Section 2: Residential Specifications

2.1 Operational Specifications

Four operational scenarios were agreed to be progressed with Vale of Glamorgan Council.

Operational emission scenarios		
Reference	Space heating demand	Energy Use Intensity (EUI)
AD: L (Wales) 2025	N/A	N/A
AECB CarbonLite	40 kWh/m²/yr	N/A
B&NES	30 kWh/m²/yr	40 kWh/m²/yr
LETI	15 kWh/m²/yr	40 kWh/m²/yr

Due to the high quality fabric required by Approved Document L (Wales) Volume 1 - Dwellings 2022 Appendix E identical u-values are targeted for all operational scenarios.

The variations that will differentiate operational performance, and therefore emissions, are instead quality of build (improved airtightness and mitigation of thermal bridging), quality of external door and window specification and the efficiency and optimisation of the technological installations. Only windows and technologies are likely to significantly impact the related construction emissions and costs: PHribbon outputs will make it possible to immediately identify the differences associated with these particular building components.

Specifications developed for these four scenarios are listed in 2.1.1 AD: L (Wales) 2025, 2.1.2 AECB CarbonLite, 2.1.3 B&NES and 2.1.4 LETI.

Photovoltaic provisions are all based upon balancing an EUI of 40 kWh/m²/yr to remain constant throughout the carbon and costing exercises: evidently this will demonstrate shortfalls in generation and not achieve net zero where the calculated EUI is higher.

Photovoltaic provisions		
Typology	Panels per dwelling	Generation
HT 211	5	70 $kWh/m^2_{footprint}$
HT 421	12	61 $kWh/m^2_{footprint}$
HT 641	18	72 $kWh/m^2_{footprint}$

Monocrystalline photovoltaic panels with a nominal output of 400W per panel are assumed.

2.1.1 AD: L (Wales) 2025

Initial proposals sought to establish and use the fabric parameters for Approved Document L (Wales) 2025. However, engagement with Welsh Government revealed the emerging legislation is still in its infancy and such detail has not been developed. Fabric u-values are therefore from Approved Document L (Wales) Volume 1 - Dwellings 2022 Appendix E with the ventilation strategy adjusted to MEV to align with The Future Homes and Buildings Standard: 2023 consultation for England.

Building Fabric	
Air permeability Thermal bridges	5.00 $m^3/m^2/hr$ 0.200 W/mK
Doors & Windows	
Frames U_f Installation thermal bridging Glazing U_g Glazing g-value Glazing edge	1.400 W/m^2K uPVC 0.040 W/mK 1.120 W/m^2K double low-e glazing 16mm Ar 0.64 0.040 W/mK
Ventilation Strategy	
Ventilation rate Ventilation unit Heat recovery efficiency Ducting Duct insulation (inlet/ exhaust)	$30m^3$ per person per hour via MEV MEV N/A (extract only)
Heating	
ASHP SCOP Controls	Generic 3.30 On/off

Appendix E currently establishes the minimum performance specification for grant-funded social housing built in Wales. Using this as the baseline responds to the Welsh Government aspiration to align market and social housing performance requirements.

2.1.2 AECB CarbonLite

AECB CarbonLite Building Standard was developed by the Association for Environment Conscious Building (AECB) to apply a less onerous demand-based performance standard than Passivhaus for the UK context. Excepting airtightness and ventilation rate, the values below are not prescribed by the AECB but were developed to ensure the least favourable typology (HT 641) could demonstrate compliance.

Building Fabric	
Air permeability Thermal bridges	1.50 $m^3/m^2/hr$ 0.050 W/mK
Doors & Windows	
Frames U_f Installation thermal bridging Glazing U_g Glazing g-value Glazing edge	0.810-0.850 W/m^2K Rehau Artevo uPVC 0.040 W/mK 1.190 W/m^2K double glazing (4w-16Ar-KS4) 0.64 0.025 W/mK
Ventilation Strategy	
Ventilation rate Ventilation unit Heat recovery efficiency Ducting Duct insulation (inlet/ exhaust)	30m^3 per person per hour via MVHR EnviroVent energiSava 300 84% Semi-rigid radial 50mm closed cell Armaflex
Heating	
ASHP SCOP Controls	Vaillant aroTHERM plus 4.01 On/off

2.1.3 B&NES

B&NES heating demand and EUI targets reflect the policy aspirations of Bath & North East Somerset. The values below are not prescribed by B&NES but were developed to ensure the least favourable typology (HT 641) could demonstrate compliance.

Building Fabric	
Air permeability Thermal bridges	1.05 m³/m²/hr 0.025 W/mK
Doors & Windows	
Frames U_f Installation thermal bridging Glazing U_g Glazing g-value Glazing edge	0.810-0.850 W/m²K Rehau Artevo uPVC 0.040 W/mK 0.55 W/m²K triple glazing (4-18Ar-4-18Ar-4) 0.63 0.025 W/mK
Ventilation Strategy	
Ventilation rate Ventilation unit Heat recovery efficiency Ducting Duct insulation (inlet/exhaust)	30m³ per person per hour via MVHR EnviroVent energiSava 400 84% Semi-rigid radial 50mm closed cell Armaflex
Heating	
ASHP SCOP Controls	Vaillant aroTHERM plus 4.01 Acc. to ambient temperature

2.1.4 LETI

LETI performance standards were developed by the Low Energy Transformation Initiative (LETI), formerly the London Energy Transformation Initiative, as net zero building standards applying demand-based performance targets within the UK context. Excepting ventilation rate, the values below are not prescribed by LETI but were developed to ensure the least favourable typology (HT 641) could demonstrate compliance.

Building Fabric	
Air permeability	0.50 $m^3/m^2/hr$
Thermal bridges	-0.050 W/mK
Doors & Windows	
Frames U_f	0.810-0.850 W/m^2K Rehau Artevo uPVC
Installation thermal bridging	0.009-0.023
Glazing U_g	0.55 W/m^2K triple glazing (4-18Ar-4-18Ar-4)
Glazing g-value	0.63
Glazing edge	0.025 W/mK
Ventilation Strategy	
Ventilation rate	30m^3 per person per hour via MVHR
Ventilation unit	Zehnder ComfoAir 225
Heat recovery efficiency	92%
Ducting	Semi-rigid radial
Duct insulation (inlet/ exhaust)	50mm closed cell Armaflex
Heating	
ASHP	Vaillant aroTHERM plus
SCOP	4.01
Controls	Acc. to ambient temperature

2.2 Embodied Scenarios

The high quality fabric of Approved Document L (Wales) Volume 1 - Dwellings 2022 Appendix E is equally applied to all embodied scenarios to target identical fabric u-values. This demonstrates the potential upfront carbon reductions available without impacting the operational performance of the buildings.

As in 2.1 Operational Scenarios the variations that will impact operational performance, and therefore emissions, are instead quality of build (improved airtightness and mitigation of thermal bridging), quality of external door and window specification and the efficiency and optimisation of the technological installations. Only windows and technologies are likely to significantly impact the related construction emissions and costs: PHribbon outputs will make it possible to immediately identify the differences associated with these particular building components.

Constructional specifications developed for the four scenarios use readily available materials that can demonstrate appropriate regulatory compliance. Relevant constructions for carbon and costing are listed in 2.2.1 Masonry with PIR, 2.2.2 140mm Stud Mineral Wool & PIR, 2.2.3 140mm Stud Woodfibre and 2.2.4 Twin Stud Cellulose.

Final internal finishes (carpets, paint, etc.), fixtures and fittings have been excluded from the analysis as the carbon intensity of such items varies significantly depending on specification. Exclusion of these items focuses the attention of the study on building fabric and services.

2.2.1 Masonry with PIR

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Sand & cement screed on 500 gauge polythene separating layer	65
PIR insulation	200
Concrete slab on 1200 gauge polythene damp proof membrane	150
External Walls	
Plasterboard with skim	15
Battens to form service zone	38x47
Passive Purple Internal Vapour Control Paint	
Forterra Evalast aggregate block	100
PIR insulation with all joints taped	165
Ventilated cavity	50
Brickwork	103
Party Walls	
Sand & cement plaster	13
Blockwork	100
Cavity fully filled with ROCKWOOL	50
Blockwork	100
Sand & cement plaster finish	13
Internal Walls	
Wet plaster finish	15
Blockwork	100
Wet plaster finish	15
Intermediate Floor	
Chipboard floor finish	22
SJL45 STEICOjoist partially filled with ROCKWOOL (100mm)	300
Plasterboard with skim	12.5
Separating Floor	
Sand & cement screed	65
Damp proof membrane	0.2
REGUPOL sonus curve 8* resilient layer	
Prestressed concrete beams (50mm concrete topping on 100mm block infill)	150
Metal suspended ceiling system with ROCKWOOL (50mm) over ceiling board	200
Plasterboard with skim	12.5
Roof	
Plasterboard with skim	15
Battens to form service zone over 500 gauge polythene vapour control layer	38x47
Timber ceiling chord fully filled with ROCKWOOL Thermal Insulation Roll	
ROCKWOOL Thermal Insulation Roll	100
Ventilated attic	300
Timber trusses overlaid with breather membrane	
Tile battens	25x38
Concrete tiles	

2.2.2 140mm Stud Mineral Wool & PIR

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Sand & cement screed on 500 gauge polythene separating layer	65
XPS insulation on 1200 gauge polythene damp proof membrane	250
Reinforced concrete beam with Thermalite FLOORBLOCK infill	150
External Walls	
Plasterboard with skim	15
Battens to form service zone	38x47
PIR insulation	80
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Timber studs fully filled with Isover Frame Roll 32	140
Panelvent sheathing board	12
Ventilated cavity	50
Brickwork	103
Party Walls	
Plasterboard (12.5x2) with skim finish	25
Timber studs fully filled with ISOVER Frame Roll 32	89
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Cavity fully filled with ISOVER Frame Roll 32	50
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Timber studs fully filled with ISOVER Frame Roll 32	89
Plasterboard (12.5x2) with skim finish	25
Internal Walls	
Plasterboard with skim finish	12.5
Timber studs partially filled with ISOVER Frame Roll 32 (50mm)	89
Plasterboard with skim finish	12.5
Intermediate Floor	
Chipboard floor finish	22
SJL45 STEICOjoist partially filled with ISOVER Frame Roll 32 (100mm)	300
Plasterboard with skim	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m³)	18
253mm metal web joists partially filled with mineral wool quilt (100mm)	253
Resilient bars (16mm) with plasterboard (2x15mm) with joints taped	16+30
Metal suspended ceiling system (150mm) with plasterboard with skim	150+15
Roof	
Plasterboard with skim	15
Battens to form service zone over 500 gauge polythene vapour control layer	38x47
Timber ceiling chord fully filled with KNAUF Earthwool Loft Roll 44	100
KNAUF Earthwool Loft Roll 44	300
Ventilated attic	
Timber trusses overlaid with breather membrane	100x38
Tile battens	25x38
Clay tiles	

2.2.3 140mm Stud Woodfibre

Construction	Size (mm)
Ground Floor	
Reinforced concrete raft on 500 gauge polythene separating layer	150
Jackon ATLAS XPS raft formwork	280
External Walls	
Plasterboard with skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Timber studs fully filled with Gutex Thermofibre	140
Gutex Mulitherm	160
Ventilated cavity	50
Brickwork	103
Party Walls	
Plasterboard (12.5x2) with skim finish	25
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Timber studs fully filled with Warmcel cellulose insulation	89
OSB	9
Cavity fully filled with Warmcel cellulose insulation	60
OSB	9
Timber studs fully filled with Warmcel cellulose insulation	89
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Plasterboard (12.5x2) with skim finish	25
Internal Walls	
Plasterboard with skim finish	12.5
Timber studs partially filled with Gutex Thermofibre (50mm)	89
Plasterboard with skim finish	12.5
Intermediate Floor	
Chipboard floor finish	22
SJL45 STEICOjoist partially filled with Gutex Thermofibre (100mm)	300
Plasterboard with skim	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m^3)	18
253mm metal web joists partially filled with mineral wool quilt (100mm)	253
Resilient bars (16mm) with plasterboard (2x15mm) with joints taped	16+30
Metal suspended ceiling system (150mm) with plasterboard with skim	150+15
Roof	
Plasterboard with skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Timber ceiling chord fully filled with IndiNature IndiTherm Hemp Flexibatt	100
IndiNature IndiTherm Hemp Flexibatt	300
Ventilated attic	
Timber trusses overlaid with breather membrane	100x38
Tile battens	25x38
Spanish slate	

2.2.4 Twin Stud Cellulose

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Chipboard floor finish	22
SJL45 STEICOjoist fully filled with Warmcel cellulose insulation	390
External Walls	
Plasterboard with skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Timber studs fully filled with Warmcel cellulose insulation	292
Panelvent sheathing board	12
Ventilated cavity	50
Brickwork	103
Party Walls	
Plasterboard (12.5x2) with skim finish	25
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Timber studs fully filled with Warmcel cellulose insulation	89
OSB	9
Cavity fully filled with Warmcel cellulose insulation	60
OSB	9
Timber studs fully filled with Warmcel cellulose insulation	89
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Plasterboard (12.5x2) with skim finish	25
Internal Walls	
Plasterboard with skim finish	12.5
Timber studs fully filled with Warmcel cellulose insulation	89
Plasterboard with skim finish	12.5
Intermediate Floor	
Chipboard floor finish	22
SJL45 STEICOjoist partially filled with Warmcel cellulose insulation (100mm)	300
Plasterboard with skim	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m³)	18
253mm metal web joists partially filled with mineral wool quilt (100mm)	253
Resilient bars (16mm) with plasterboard (2x15mm) with joints taped	16+30
Metal suspended ceiling system (150mm) with plasterboard with skim	150+15
Roof	
Plasterboard with skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Timber ceiling chord fully filled with Warmcel cellulose insulation	100
Warmcel cellulose insulation	215
Ventilated attic	
Timber trusses overlaid with breather membrane	100x38
Tile battens	25x38
Welsh slate	

Section 3: Non-Residential Specifications

3.1 Operational Specifications

Four operational scenarios were agreed to be progressed with Vale of Glamorgan Council.

Operational emission scenarios		
Reference	Space heating demand	Energy Use Intensity (EUI)
AD: L (Wales) 2025	N/A	N/A
AECB CarbonLite	40 kWh/m²/yr	N/A
B&NES	30 kWh/m²/yr	55 kWh/m²/yr
LETI	15 kWh/m²/yr	55 kWh/m²/yr

As Section 2: Residential Specifications fabric u-values for all scenarios are derived from Approved Document L (Wales) Volume 1 - Dwellings 2022 Appendix E. This applies more onerous targets than Approved Document L (Wales) Volume 2 - Buildings other than dwellings 2022 but is more appropriate for the smaller, detached buildings explored as non-residential typologies which do not achieve favourable form factors. As previously, identical u-values are targeted for all operational scenarios.

Specifications developed for these four scenarios are listed in 3.1.1 AD: L (Wales) 2025, 3.1.2 AECB CarbonLite, 3.1.3 B&NES and 3.1.4 LETI.

Photovoltaic provisions are all based upon balancing an EUI of 55 kWh/m²/yr to remain constant throughout the carbon and costing exercises: evidently this will demonstrate shortfalls in generation and not achieve net zero where the calculated EUI is higher.

Photovoltaic provisions		
Typology	Panels per building	Generation
OF 315	56	55 $kWh/m^2_{footprint}$
OF 1492	266	55 $kWh/m^2_{footprint}$

Monocrystalline photovoltaic panels with a nominal output of 400W per panel are assumed.

3.1.1 AD: L (Wales) 2025

Initial proposals sought to establish and use the fabric parameters for Approved Document L (Wales) 2025. However, engagement with Welsh Government revealed the emerging legislation is still in its infancy and such detail has not been developed. Fabric u-values are therefore from Approved Document L (Wales) Volume 1 - Dwellings 2022 Appendix E with the ventilation strategy adjusted to MEV to reflect more stringent ventilation requirements.

Building Fabric	
Air permeability Thermal bridges	5.00 $m^3/m^2/hr$ 0.200 W/mK
Doors & Windows	
Frames U_f Installation thermal bridging Glazing U_g Glazing g-value Glazing edge	1.400 W/m^2K uPVC 0.040 W/mK 1.120 W/m^2K double low-e glazing 16mm Ar 0.64 0.040 W/mK
Ventilation Strategy	
Ventilation rate Ventilation unit Heat recovery efficiency Ducting Duct insulation (inlet/ exhaust)	$20m^3$ per person per hour via MEV MEV N/A (extract only)
Heating	
ASHP SCOP Controls	Generic 3.30 On/off

3.1.2 AECB CarbonLite

AECB CarbonLite Building Standard was developed by the Association for Environment Conscious Building (AECB) to apply a less onerous demand-based performance standard than Passivhaus for the UK context. Excepting airtightness and ventilation rate, the values below are not prescribed by the AECB but were developed to ensure the least favourable typology (OF 315) could demonstrate compliance.

Building Fabric	
Air permeability Thermal bridges	1.50 $m^3/m^2/hr$ 0.100 W/mK
Doors & Windows	
Frames U_f Installation thermal bridging Glazing U_g Glazing g-value Glazing edge	0.810-0.850 W/m^2K Rehau Artevo uPVC 0.040 W/mK 1.190 W/m^2K double glazing (4w-16Ar-KS4) 0.64 0.025 W/mK
Ventilation Strategy	
Ventilation rate Ventilation unit Heat recovery efficiency Ducting Duct insulation (inlet/ exhaust)	20m^3 per person per hour via MVHR EnviroVent energiSava 300 84% Semi-rigid radial 50mm closed cell Armaflex
Heating	
ASHP SCOP Controls	Vaillant aroTHERM plus 4.01 On/off

3.1.3 B&NES

B&NES heating demand targets reflect the policy aspirations of Bath & North East Somerset for residential development which, combined with the LETI EUI target, offers a useful comparator along the spectrum of low energy building performance. The values below are not prescribed by B&NES but were developed to ensure the least favourable typology (OF 315) could demonstrate compliance.

Building Fabric	
Air permeability Thermal bridges	1.50 $m^3/m^2/hr$ 0.050 W/mK
Doors & Windows	
Frames U_f Installation thermal bridging Glazing U_g Glazing g-value Glazing edge	0.810-0.850 W/m^2K Rehau Artevo uPVC 0.040 W/mK 0.55 W/m^2K triple glazing (4-18Ar-4-18Ar-4) 0.63 0.025 W/mK
Ventilation Strategy	
Ventilation rate Ventilation unit Heat recovery efficiency Ducting Duct insulation (inlet/exhaust)	$20m^3$ per person per hour via MVHR EnviroVent energiSava 400 84% Semi-rigid radial
Heating	
ASHP SCOP Controls	Vaillant aroTHERM plus 4.01 Acc. to ambient temperature

3.1.4 LETI

LETI performance standards were developed by the Low Energy Transformation Initiative (LETI), formerly the London Energy Transformation Initiative, as net zero building standards applying demand-based performance targets within the UK context. Excepting ventilation rate, the values below are not prescribed by LETI but were developed to ensure the least favourable typology (OF 315) could demonstrate compliance.

Building Fabric	
Air permeability Thermal bridges	0.50 $m^3/m^2/hr$ -0.050 W/mK
Doors & Windows	
Frames U_f Installation thermal bridging Glazing U_g Glazing g-value Glazing edge	0.810-0.850 W/m^2K Rehau Artevo uPVC 0.009-0.023 0.55 W/m^2K triple glazing (4-18Ar-4-18Ar-4) 0.63 0.025 W/mK
Ventilation Strategy	
Ventilation rate Ventilation unit Heat recovery efficiency Ducting Duct insulation (inlet/ exhaust)	20m^3 per person per hour via MVHR Zehnder ComfoAir 225 92% Semi-rigid radial 50mm closed cell Armaflex
Heating	
ASHP SCOP Controls	Vaillant aroTHERM plus 4.01 Acc. to ambient temperature

3.2 Embodied Scenarios

The high quality fabric of Approved Document L (Wales) Volume 1 - Dwellings 2022 Appendix E is equally applied to all embodied scenarios to target identical fabric u-values. This demonstrates the potential upfront carbon reductions available without impacting the operational performance of the buildings.

As in 3.1 Operational Scenarios the variations that will impact operational performance, and therefore emissions, are instead quality of build (improved airtightness and mitigation of thermal bridging), quality of external door and window specification and the efficiency and optimisation of the technological installations. Only windows and technologies are likely to significantly impact the related construction emissions and costs: PHribbon outputs will make it possible to immediately identify the differences associated with these particular building components.

Constructional specifications developed for the four scenarios use readily available materials that can demonstrate appropriate regulatory compliance. Relevant constructions for carbon and costing are listed in 3.2.1 Masonry with PIR, 3.2.2 Steel Frame with PIR Panels, 3.2.3 Timber Stud Woodfibre and 3.2.4 Twin Stud Cellulose.

Final internal finishes (carpets, paint, etc.), fixtures and fittings have been excluded from the analysis as the carbon intensity of such items varies significantly depending on specification. Exclusion of these items focuses the attention of the study on building fabric and services.

3.2.1 Masonry with PIR

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Sand & cement screed on 500 gauge polythene separating layer	65
PIR insulation	200
Concrete slab on 1200 gauge polythene damp proof membrane	150
External Walls	
Plasterboard with skim	15
Battens to form service zone	38x47
Passive Purple Internal Vapour Control Paint	
Forterra Evalast aggregate block	100
PIR insulation with all joints taped	165
Ventilated cavity	50
Brickwork	103
Internal Walls	
Wet plaster finish	15
Blockwork	100
Wet plaster finish	15
Separating Floor	
Sand & cement screed	65
Damp proof membrane	0.2
REGUPOL sonus curve 8* resilient layer	
Prestressed concrete beams (50mm concrete topping on 100mm block infill)	150
Metal suspended ceiling system with ROCKWOOL (50mm) over ceiling board	200
Plasterboard with skim	12.5
Warm Roof	
Metal suspended ceiling system (150mm) with plasterboard with skim	150 + 15
Primary steel rafters protected with intumescent paint	
Z-purlins	140
OSB3	18
Rockwool HARDROCK Multi-Fix	320
Battens to form ventilation zone	47x38
Standing seam with breather membrane on OSB3 substrate	9
Additional Structure	
Steel posts & beams	

3.2.2 Steel Frame with PIR Panels

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Sand & cement screed on 500 gauge polythene separating layer XPS insulation on 1200 gauge polythene damp proof membrane Reinforced concrete beam with Thermalite FLOORBLOCK infill	65 250 150
External Walls	
Plasterboard (12.5x2) with skim Primary steel frame protected with intumescent paint Z-purlins Kingspan QuadCore AWP Supreme Wall Panel with all joints taped internally	25 140 150
Internal Walls	
Plasterboard with skim Gypframe 70 S 50 ‘C’ Studs partially filled with Isover APR 1200 (50mm) Plasterboard with skim	15 70 15
Separating Floor	
Cellecta Screedboard 30 adhered by Cellecta Pro Adhesive Cast in-situ concrete (100mm minimum) within profiled metal deck Metal suspended ceiling system with ROCKWOOL (25mm) over ceiling board Plasterboard with skim	30 150 200 15
Warm Roof	
Metal suspended ceiling system (150mm) with plasterboard with skim Primary steel frame protected with intumescent paint Z-purlins Kingspan QuadCore KS1000RW Roof Panel with all joints taped internally	150 + 15 140 150
Additional Structure	
Steel posts & beams	

3.2.3 Timber Stud Woodfibre

Construction	Size (mm)
Ground Floor	
Reinforced concrete raft on 500 gauge polythene separating layer	150
Jackon ATLAS XPS raft formwork	280
External Walls	
Plasterboard with skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Timber studs fully filled with Gutex Thermofibre	140
Gutex Mulitherm	160
Battens to form ventilated cavity	47x38
Rockpanel	9
Internal Walls	
Plasterboard with skim finish	12.5
Timber studs partially filled with Gutex Thermofibre (50mm)	89
Plasterboard with skim finish	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m³)	18
253mm metal web joists partially filled with mineral wool quilt (100mm)	253
Resilient bars (16mm) with plasterboard (2x15mm) with joints taped	16+30
Metal suspended ceiling system (150mm) with plasterboard with skim	150+15
Warm Roof	
Plasterboard with skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB as airtightness & vapour control layer	12.5
Timber I-joists fully filled with Gutex Thermofibre insulation	315
Panelvent sheathing board	12
Battens to form ventilation zone	47x38
Standing seam with breather membrane on OSB3 substrate	9
Additional Structure	
LVL posts & beams	

3.2.4 Twin Stud Cellulose

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Chipboard floor finish SJL45 STEICOjoist fully filled with Warmcel cellulose insulation	22 390
External Walls	
Plasterboard with skim Battens to form service zone SMARTPLY ProPassiv OSB as airtightness & vapour control layer Timber studs fully filled with Warmcel cellulose insulation Panelvent sheathing board Battens to form ventilated cavity Rockpanel	15 38x47 12.5 292 12 50 9
Internal Walls	
Plasterboard with skim finish Timber studs fully filled with Warmcel cellulose insulation Plasterboard with skim finish	12.5 89 12.5
Separating Floor	
Cellecta Screedboard 28 OSB deck (min. 600kg/m³) 253mm metal web joists partially filled with mineral wool quilt (100mm) Resilient bars (16mm) with plasterboard (2x15mm) with joints taped Metal suspended ceiling system (150mm) with plasterboard with skim	28 18 253 16+30 150+15
Roof	
Plasterboard with skim Battens to form service zone SMARTPLY ProPassiv OSB as airtightness & vapour control layer Timber I-joists fully filled with Warmcel cellulose insulation Panelvent sheathing board Battens to form ventilation zone Standing seam with breather membrane on OSB3 substrate	15 38x47 12.5 315 12 47x38 9
Additional Structure	
Glulam posts & beams	

Unit 2
Chapel Barns
Merthyr Mawr
Bridgend
CF32 0LS

T: 01656 656267
W: www.spring-consultancy.co.uk

Vale of Glamorgan Council

Net Zero Carbon Buildings Feasibility Study and Cost Assessment

Work Stage 2E

Technical Feasibility

February 2024

Architecture
Low Energy Consultancy
Civil Engineering
Structural Engineering
Urban Design

Contents

spring design

Section 1: Introduction

1.1 Introduction

Spring Design Consultancy Limited is appointed to assist Vale of Glamorgan Council in developing suitably evidenced Net Zero policy to guide, assess and determine applications for new-build residential and non-residential development within the emerging Replacement Local Development Plan 2021-2036.

This process has been divided into distinct work stages:

Work Stage 1	A - Policy Review B - Policy Approach C - Evidence Base
Work Stage 2	D – Methodologies E - Technical Feasibility
Work Stage 3	F - Cost Analysis
Work Stage 4	G - Evidence H - Cost Implications I - Scrutiny Skillset
Work Stage 5	Examination

This report summarises the assumptions informing and the results of whole life carbon assessment of Work Stage 2E - Technical Feasibility.

1.2 Emission Targets

1.2.1 Operational Targets

Operational energy relates to the amount of energy required to operate a building. For this exercise, two measures of operational energy were quantified: Space Heating Demand and Energy Use Intensity (EUI) which both use the metric of kWh/m²/yr.

Space heating demand refers to the amount of energy required to maintain a constant internal temperature of 20°C annually based on Treated Floor Area (TFA). This does not factor in the in-/ efficiencies of the heating system but quantifies the necessary input of heat.

Energy use intensity (EUI) relates to the sum of all energy use by a building on an annual basis based on Gross Internal Area (GIA). This can be delivered via the grid or by on-site renewables and accounts for space heating, hot water, lighting and all unregulated usage in occupation (e.g. all appliance usage) - factoring in system in/ efficiencies - but excludes EV charging.

Four operational scenarios were agreed with VoGC using identical fabric specifications derived from Approved Document L (Wales) 2022 Appendix E.

Operational emission scenarios		
Reference	Space heating demand	Energy use intensity (EUI)
AD: L (Wales) 2025	N/A	N/A
AECB CarbonLite	40 kWh/m²/yr	75 kWh/m²/yr
B&NES	30 kWh/m²/yr	40 kWh/m²/yr res. 50 kWh/m²/yr non.
LETI	15 kWh/m²/yr	40 kWh/m²/yr res. 50 kWh/m²/yr non.

These generally follow the standards for which they are named, however: in recognition of modelling the worst-case scenarios (see 3.3 Principles), EUI targets are slightly relaxed from LETI recommendations.

1.2.2 Embodied Targets

Embodied energy (also embodied carbon or life cycle embodied carbon) refers to the total greenhouse gas emissions and removals associated with materials and construction processes throughout the whole life cycle of an asset including its disposal.

Embodied energy is measured in kg CO_2e/m^2.

As it has historically received less attention than operational energy, no specific targets were set for embodied energy. Instead, it was considered more appropriate to establish what current practice achieves and use this as a baseline to leverage improvements.

Identical u-values were targeted for all operational scenarios with changes concentrated in the quality of the design and construction (improved airtightness and thermal bridge mitigation), quality of external door and window specification and the optimisation of heating and ventilation technologies.

Four scenarios were agreed with VoGC to represent the residential and non-residential typologies.

Embodied emission scenarios		
Reference	Residential	Non-Residential
Masonry	Masonry with PIR	
Framed	140mm Stud with Mineral Wool & PIR	Steel Frame with PIR Panels
Timber	140mm Stud with Woodfibre	
Timber Optimised	Twin Stud Cellulose	

Inclusions and exclusions for embodied outputs vary slightly between different assessment methodologies (e.g. upfront, WLCA, LETI, RIBA, etc.). Select outputs are presented within 2: Summary.

1.3 Glossary

1.3.1 Carbon Definitions

Clarity and consistency in the basic terminology used to discuss carbon and Net Zero is key to ensuring meaningful outcomes.

Carbon Definitions for the Built Environment, Buildings and Infrastructure: Improving Consistency in Whole Life Carbon Assessment and Reporting (2023) is a collaboration between professions throughout the construction industry including the Chartered Institute of Building Service Engineers (CIBSE), Institution of Civil Engineers (ICE), Institution of Structural Engineers (IStructE), Low Energy Transformation Initiative (LETI), Royal Institute of British Architects (RIBA), Royal Institute of Chartered Surveyors (RICS), UK Green Building Council and the Whole Life Carbon Network (WLCN) and applies the following.

Greenhouse Gases (GHG)
often 'carbon emissions' in general usage
'Greenhouse Gases' are constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds.

Whole Life Carbon
'Whole Life Carbon' emissions are the sum total of all asset related GHG emissions and removals, both operational and embodied over the life cycle of an asset including its disposal (Modules: A0-A5; B1-B7; B8 optional; C1-C4, all including biogenic carbon, with A0 assumed to be zero for buildings). Overall Whole Life Carbon asset performance includes separately reporting the potential benefits or loads from future energy or material recovery, reuse, and recycling and from exported utilities (Modules D1, D2).

Embodied Carbon *or* **Life Cycle Embodied Carbon**
'Embodied Carbon' emissions of an asset are the total GHG emissions and removals associated with materials and construction processes throughout the whole life cycle of an asset (Modules A0-A5, B1-B5, C1-C4, with A0 assumed to be zero for buildings).

Upfront Carbon - Buildings
'Upfront Carbon' emissions are the GHG emissions associated with materials and construction processes up to practical completion (Modules A0-A5). Upfront carbon excludes the biogenic carbon sequestered in the installed products at practical completion.

Operational Carbon - Energy, Buildings
'Operational Carbon - Energy' (Module B6) are the GHG emissions arising from all energy consumed by an asset in-use, over its life cycle.

Carbon Sequestration
'Carbon Sequestration' is the process by which carbon dioxide is removed from the atmosphere and stored within a material - e.g. stored as 'Biogenic Carbon' in 'Biomass' by plants/ trees through photosynthesis and other processes.

Biogenic Carbon
'Biogenic Carbon' refers to the carbon removals associated with carbon sequestration into biomass as well as any emissions associated with this sequestered carbon. Biogenic carbon must be reported separately if reporting only upfront carbon but should be included in the total if reporting embodied carbon or whole life carbon.

These definitions only address the GHGs with Global Warming Potential assigned by the Intergovernmental Panel on Climate Change (IPCC). A0 is generally assumed to be zero for buildings.

1.3.2 Net Zero Definitions

Net Zero (whole life) Carbon
A 'Net Zero (whole life) Carbon' Asset is one where the sum total of all asset related GHG emissions, both operational and embodied, over an asset's life cycle (Modules A0-A5, B1–B8, C1-C4) are minimized, which meets local carbon, energy and water targets or limits, and with residual 'offsets', equals zero.

To meet the requirements of 'Net Zero (whole life) Carbon' the definitions for 'Net Zero Upfront Carbon', Net Zero Embodied Carbon', 'Net Zero Capital Carbon', Net Zero operational Carbon - Energy', 'Net Zero Operational Carbon - Infrastructure', 'Net Zero In-Use Carbon Asset' and 'Net Zero Operational Carbon - Water' must also be individually met as applicable.

Net Zero Carbon Embodied Carbon *or*
Net Zero Life Cycle Embodied Carbon
A 'Net Zero Embodied Carbon' asset is one where the sum total of GHG emissions and removals over an asset's life cycle (Modules A0-A5, B1-B5 and C1-C4) are minimized, which meets local carbon targets or limits (e.g. kgCO_2e/m²), and with additional 'offsets', equals zero.

Net Zero Upfront Carbon
A 'Net Zero Upfront Carbon' asset is where the sum of GHG emissions, excluding 'biogenic carbon', from Modules A0-A5 is minimized, which meets local carbon targets or limits (e.g. kgCO_2e/m²), and with additional 'offsets', equals zero.

Net Zero Operational Carbon - Energy
A 'Net Zero Operational Carbon - Energy' asset is one where no fossil fuels are used, all energy use Module B6) has been minimized, meets the local energy use target or limit (e.g. kWh/m²/a) and all energy use is generated on- or off- site using renewables that demonstrate additionality. Direct emissions from renewables and any upstream emissions are 'offset'.

Direct emissions must include CH_4 and N_2O emissions from the combustion of biomass and biodiesel fuels. Upstream emissions include: direct and indirect emissions from energy generation and distribution, WTT emissions for energy consumed in the building and from energy generation and distribution.

Net Zero Operational Carbon - Water
A 'Net Zero Operational Carbon - Water' asset is one where water use (Module B7) is minimized, meets local water targets or limits (e.g. litres/person/year) and where those GHG emissions arising from water supply and wastewater treatment are 'offset'.

Net Zero In-Use Asset
A 'Net Zero In-Use Carbon Asset' is one where on an annual basis the sum total of all asset related GHG emissions, both operational and embodied, (Modules B1-B8) are minimized, which meets local carbon, energy and water targets or limits, and with residual 'offsets', equals zero.

Additionality
Procurement of renewable energy for the asset's use which results in new installed renewable energy capacity that otherwise would not have occurred had the intervention not taken place.

Carbon Neutral
All carbon emissions are balanced with offsets based on carbon removals or avoided emissions.

Absolute Zero Carbon
Eliminating all carbon emissions without the use of credits.

1.3.3 Reference Terms

ASHP
Air source heat pump: heating and hot water from electrical source. Efficiency described by COP/ SCOP.

COP/ SCOP
(Seasonal) coefficient of performance: rate of conversion of electricity to useful heat energy.

MEV
Mechanical extract ventilation: constant mechanical extraction from 'wet' rooms (bathroom, kitchen, utility, WC, etc.) with fresh air from trickle vents circulated through the building by depressurisation.

MVHR
Mechanical ventilation with heat recovery: ventilation systems that ensure a constant throughput of fresh, filtered air. 'Waste' heat is transferred from outgoing exhaust air to incoming fresh air to pre-warm it and reduce heating demand.

CO_2e Emissions
Equivalent carbon dioxide emissions calculated using the global warming potential (GWP) of exhaust gases.

Form Factor
Expresses the relationship between the treated floor area and area of the thermal envelope. A better form factor signifies a more efficiently designed building.

Thermal Envelope
The insulated components (floors, walls, ceilings) that separate internal and external volumes. Note this often excludes features such as porches and balconies.

Treated Floor Area (TFA)
The floor area of the rooms within the building that are heated. It excludes the areas of internal partitions, doors, stairs and unusable spaces.

Section 2: Summary

2.1 Executive Summary

Achieving Net Zero Carbon in the built environment is critical to mitigating anthropogenic climate change and meeting climate commitments.

As evidenced within this study, substantial operational carbon savings are achievable with only minor changes to building specifications and embodied carbon can be cut without compromising building performance.

This report assesses the relative operational and embodied carbon of three residential and two non-residential new-build typologies to establish the technical feasibility of Net Zero:

- **HT 211** - 3 storey block of nine flats;
- **HT 421** - two semi-detached dwellings;
- **HT 641** - detached single family dwelling;
- **OF 315** - single storey office of 315m²;
- **SC 1492** - 2 storey school building of 1492m².

Four operational scenarios were modelled in PHPP applying identical external envelope u-values to achieve increasing levels of building performance:

- **AD: L (Wales) 2025** - future Building Regulations;
- **AECB CarbonLite** - 40 kWh/m²/yr threshold;
- **B&NES** - 30 kWh/m²/yr threshold;
- **LETI** - 15 kWh/m²/yr threshold.

Four embodied scenarios were then taken through PHribbon to achieve the LETI performance standard using a range of different constructions:

- **Masonry** - masonry + PIR;
- **Framed** - steel + PIR/ timber + mineral wool & PIR;
- **Timber** - timber + woodfibre;
- **Timber Optimised** - twin stud timber + cellulose.

In all scenarios heat pumps were applied to supply hot water and space heating. If these were substituted for any alternative heating and/ or hot water systems the associated energy use and operational emissions would be likely to increase approximately fourfold.

Headlines for operational analysis

- Heating demand reductions > 80% achievable between identical buildings by improving airtightness & thermal bridging complemented by MVHR
- EUI & CO_2e reductions of 30-40% available applying these improvements
- Reduced EUI requires 30-40% fewer PV panels to achieve Net Zero balance
- Heat pumps reduce energy required for heating & hot water demand to < 25% of the direct electric equivalent

Heating demand reductions of more than 80% were achieved for the assessed typologies while applying identical fabric u-values. This illustrates the benefit of well-considered airtightness and thermal bridge detailing with MVHR as the ventilation strategy and how this efficiently deliver low carbon buildings.

Hot water, auxiliary and household electricity loads remain constant throughout each operational scenario as no changes were made to appliances or lighting. This is to allow direct comparison of the impact of the interventions on the energy use intensity (EUI) and potential CO2e emissions: these reduce by 30-40% progressing through the operational scenarios and so require 30-40% fewer photovoltaics to meet Net Zero.

Beyond fewer photovoltaic panels, reductions in space heating demand would also translate into smaller heat pumps and heating infrastructure. This provides further opportunities for cutting embodied carbon.

Headlines for embodied analysis

- Higher-density building typologies can facilitate material efficiencies that result in lower embodied carbon
- Changing from masonry construction to timber frame reduces CO_2e 20-30%
- Timber frame with biogenic insulants can sequester 3-5x CO_2e as equivalent built in masonry with PIR insulation
- Improved form factor can achieve high performance standards with less insulation, saving embodied carbon

While the fabric specifications were developed to ensure compliance by the typologies with the worst form factor, **HT 211** illustrates how application of the same fabric standards is not the most materially efficient way of achieving high performance buildings. **SC 1492** demonstrates how improved form factor can use less depth of insulation and still achieve the same high performance standards. Terracing dwellings or building apartments is therefore a cost-effective way of reducing operational energy demand.

Before considering materiality or potential reductions to insulation thickness, significant embodied carbon savings are also possible by improving the form factor of buildings and delivering greater density. Such an approach must be balanced against placemaking and urban design aspirations but the same principle of terracing dwellings or building apartments to reduce operational carbon applies to reducing embodied carbon versus building detached, low-rise buildings.

Material and specification choices significantly impact embodied carbon. In the context of the assessed typologies, replacing masonry with timber frame reduced embodied emissions 20-30% and facilitated greater CO_2e sequestration. Further improvements are available by substituting conventional petrochemical and mineral insulants with short-rotation biogenic or recycled insulations such as hemp and cellulose.

In addition to the operational cost and carbon savings available by reducing heating demand, capital cost and embodied carbon savings can also be realised. While there are costs associated with installing MVHR units these are quickly offset by the savings available from installing smaller heating systems and requiring fewer photovoltaics to achieve the Net Zero energy demand.

Material efficiency goes beyond reducing embodied carbon: it also contributes to alleviating the complex issues of social justice and ethics. Particularly in the context of extracting and refining rare earth minerals, there are well-publicised transgressions of human rights and environmental protections. Technologies reliant upon these materials, chiefly renewables such as batteries and photovoltaics, must therefore be used as efficiently as possible in the pursuit of Net Zero and only sourced from those manufacturers who can offer visibility of their supply chains.

It is acknowledged that decarbonisation of existing buildings is critical to combatting climate change. New buildings must not contribute to this retrofit workload and so must be climate resilient, achieving the lowest embodied and operational carbon practicable. Due to the range of typologies, construction methodologies and heritage constraints present within the Vale it was considered impractical to accommodate analysis of the stock within the current scope and timeframes.

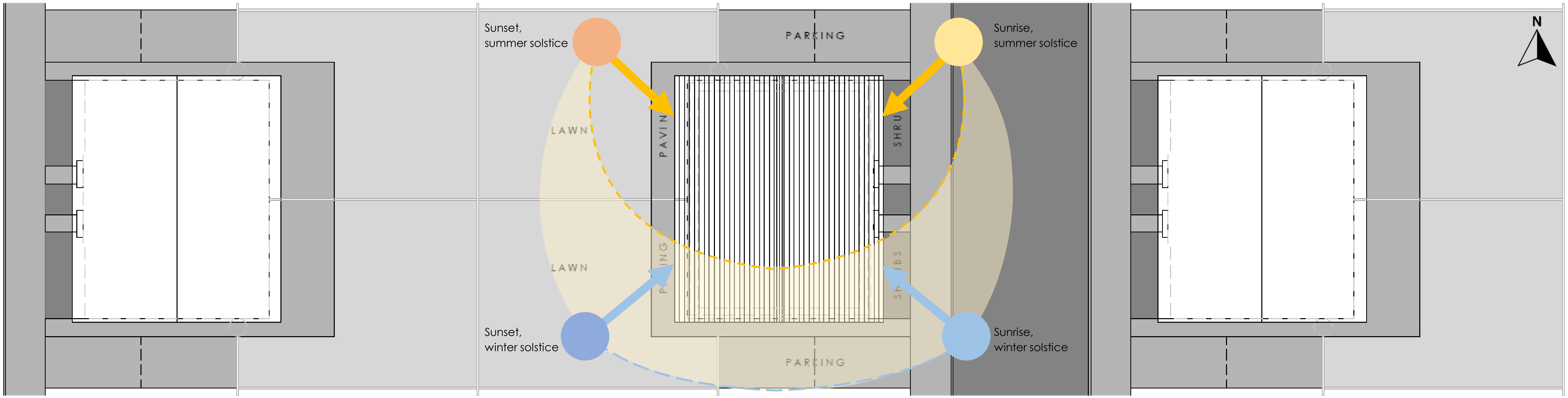


Fig. 01: Excerpt from **2740-421(02)100 - Notional Site Layout**
Not to scale.

All typologies were modelled facing East-West as the least favourable orientation for solar gains. In winter this orientation excludes the majority of sunlight, limiting heat gains that could offset space heating demand; in summer it is exposed to low angle sun that can exacerbate issues with overheating.

Residential typologies were modelled to account for units of the same scale 15.0m from the front elevation and 21.0m from the rear. Non-residential typologies have slightly greater rear offsets to reflect the scale of potential parking courts.

Distances between buildings are derived from the principles established by Manual for streets (2007). Similar units are positioned to the East and West to establish horizon shading objects and ensure the assessment remains conservative: unshaded building models would overestimate the potential of solar gains to offset space heating demand.

Operational fabric specification

- Identical ground floor, external wall and roof u-values for all scenarios (N.B. **SC 1492** able to use degraded fabric u-values due to scale of building)
- Improved: airtightness, thermal bridging, door & window specification
- Ventilation strategy improved from MEV to increasingly efficient MVHR
- ASHP used for hot water & heating: unit with improved SCOP used for AECB, B&NES + LETI scenarios

Operational	AD: L (Wales) 2025	AECB CarbonLite	B&NES	LETI
Building Fabric				
Ground floor	0.110 W/m^{2}K	0.110 W/m^{2}K	0.110 W/m^{2}K	0.110 W/m^{2}K
External wall	0.130 W/m^{2}K	0.130 W/m^{2}K	0.130 W/m^{2}K	0.130 W/m^{2}K
Roof	0.110 W/m^{2}K	0.110 W/m^{2}K	0.110 W/m^{2}K	0.110 W/m^{2}K
Air permeability	5.00 m^3/m^2/hr	1.50 m^3/m^2/hr	1.05 m^3/m^2/hr	0.50 m^3/m^2/hr
Thermal bridges	0.200 W/mK	0.100 W/mK	0.050 W/mK	-0.050 W/mK
Doors & Windows				
Frames U_f	1.400 W/m^{2}K	0.850 W/m^{2}K	0.810 W/m^{2}K	0.810 W/m^{2}K
Installation TB	0.040 W/mK	0.040 W/mK	0.040 W/mK	0.023 W/mK
Glazing U_g	1.120 W/m^{2}K DG	1.190 W/m^{2}K DG	0.550 W/m^{2}K TG	0.550 W/m^{2}K TG
Glazing g-value	0.64	0.64	0.63	0.63
Glazing edge	0.040 W/mK	0.025 W/mK	0.025 W/mK	0.025 W/mK
Ventilation Strategy				
Ventilation rate	30m^3 per person/ hr	30m^3 per person/ hr	30m^3 per person/ hr	30m^3 per person/ hr
Ventilation unit	MEV	MVHR energiSava 300	MVHR energiSava 400	Zehnder ComfoAir 225
HR efficiency	N/A (extract only)	84%	84%	92%
Heating				
ASHP	Generic	Vaillant aroTHERM	Vaillant aroTHERM	Vaillant aroTHERM
SCOP	3.30	4.10	4.10	4.10

Above is a summary of the fabric standards applied to the operational scenarios. These are expanded upon in 4: Specifications along with the embodied scenarios.

2.2 Residential

2.2.1 Operational

Modelling of the typologies clearly illustrates that application of standardised fabric specifications is not the most efficient way of delivering buildings that meet space heating demand and EUI targets. The specification, derived to ensure the compliance of heating demand for **HT 641**, results in **HT 211** overperforming by a significant margin. Discussion of the potential impact of standard specifications on the embodied carbon of buildings is continued within 2.2.2 Embodied.

In the context of this feasibility study, aligning with the analysed adopted policy by other Local Authorities, Net Zero is achieved by generating as much electricity on-site per annum as the building consumes. The reality is more complex as there are still emissions generated by buildings where photovoltaics meet the annual on-site energy demand. This is a product of the electricity generated by the photovoltaics being imported and exported to and from the grid as not all on-site generation will be immediately utilised.

Operational results are broken down into five separate metrics, tabulated individually for each typology. These were selected to evidence the correlation between thermal performance, operational emissions and the number of photovoltaics required to achieve Net Zero.

The applied metrics are:

- space heating demand;
- energy use intensity (EUI);
- annual energy use per dwelling;
- CO_2e emissions excluding photovoltaics;
- kWp of photovoltaics required to achieve Net Zero.

CO_2e emissions excluding photovoltaics describes the potential emissions if all electricity were imported from the grid. These are the cumulative emissions within a 60 year building lifecycle, applying the 'Falling Short' grid decarbonisation scenario. 5: Building Assessment explores how this is applied and explains the grid decarbonisation scenarios in more detail.

As demonstrated within the result tables, minor improvements to build quality significantly reduces operational emissions. Upgrading from the build quality of **AD: L (Wales) 2025** to **LETI** lowers energy use and associated emissions by 32-37% across the assessed typologies. 4: Specifications provides full details of the interventions applied to improve building performance.

Diminishing energy demand also requires less on-site generation to achieve Net Zero, reducing the size of photovoltaic arrays. Reducing numbers of photovoltaic panels lowers both the embodied energy and capital cost of the works. Such cost implications will be explored in Work Stage 3F - Cost Viability.

Headlines for residential typologies

- Performance of identical buildings is significantly impacted by airtightness, thermal bridging & ventilation > 80% reduction of heating demand possible
- EUI & CO_2e reductions of 35% in upgrading **AD: L (Wales) 2025** to **LETI**
- Lower EUI requires 35% fewer PV panels to achieve Net Zero balance
- Fewer PV panels reduces embodied carbon & capital cost of buildings
- Better form factor/ higher density significantly reduces heating demand

Operational outputs - HT 211					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	CO_2e emissions ex. PV (60 yrs)	kWp of PV to Net Zero per dwelling
1 AD: L (Wales) 2025	60.7 kWh/m^2/yr	44.9 kWh/m^2/yr	2,686 kWh/yr	10.10 tonnes	4.0 kWp
2 AECB CarbonLite	19.7 kWh/m^2/yr	37.5 kWh/m^2/yr	2,244 kWh/yr	8.53 tonnes	2.9 kWp
3 B&NES	13.4 kWh/m^2/yr	33.0 kWh/m^2/yr	1,974 kWh/yr	7.49 tonnes	2.5 kWp
4 LETI	3.9 kWh/m^2/yr	28.5 kWh/m^2/yr	1,705 kWh	6.44 tonnes	2.4 kWp

Operational outputs - HT 421					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	CO_2e emissions ex. PV (60 yrs)	kWp of PV to Net Zero per dwelling
1 AD: L (Wales) 2025	87.1 kWh/m^2/yr	62.5 kWh/m^2/yr	5,200 kWh	19.75 tonnes	7.6 kWp
2 AECB CarbonLite	36.7 kWh/m^2/yr	43.8 kWh/m^2/yr	3.644 kWh	13.95 tonnes	5.4 kWp
3 B&NES	28.3 kWh/m^2/yr	41.8 kWh/m^2/yr	3,478 kWh	13.30 tonnes	5.0 kWp
4 LETI	14.3 kWh/m^2/yr	40.0 kWh/m^2/yr	3,328 kWh	12.75 tonnes	4.8 kWp

Operational outputs - HT 641					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	CO_2e emissions ex. PV (60 yrs)	kWp of PV to Net Zero per dwelling
1 AD: L (Wales) 2025	79.5 kWh/m^2/yr	65.6 kWh/m^2/yr	7,242 kWh	27.20 tonnes	10.0 kWp
2 AECB CarbonLite	35.8 kWh/m^2/yr	48.4 kWh/m^2/yr	5,343 kWh	20.10 tonnes	7.4 kWp
3 B&NES	27.3 kWh/m^2/yr	46.3 kWh/m^2/yr	5,112 kWh	19.20 tonnes	7.0 kWp
4 LETI	15.1 kWh/m^2/yr	44.5 kWh/m^2/yr	4,913 kWh	18.50 tonnes	6.8 kWp

The graphs in 5: Building Assessment demonstrate how EUI is split between space heating, domestic hot water (DHW), auxiliary and household electricity. As building performance improves, heating reduces from c. 35% of total consumption to c. 6-10%.

EUI and operational emissions must be contextualised with the use of highly efficient ASHPs. As modelled, the specified units deliver heating and hot water at an effective rate of 4.1 kWh of heat for every 1 kWh input of electricity: if heating and hot water were delivered by any other system, associated energy use and resulting emissions would increase c. 400%.

2.2.2 Embodied

Modelling of the construction scenarios demonstrates how significant embodied carbon reductions can be achieved by changing what we use to build. Despite the use of different materials, all four scenarios are capable of achieving identical fabric performance and therefore identical operational emissions.

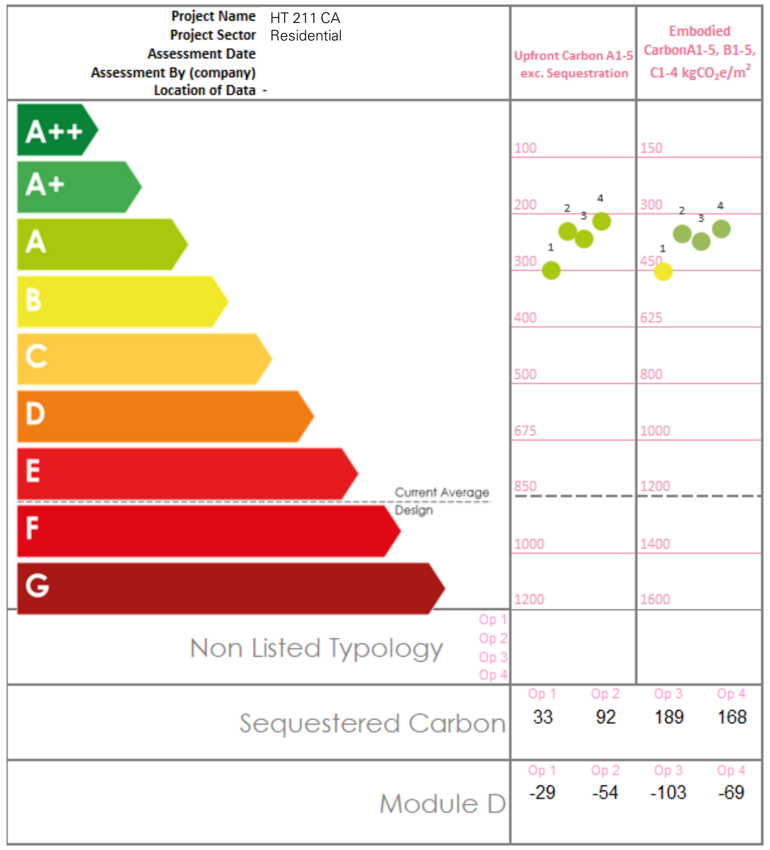
Embodied results to **LETI** standards are represented graphically by individual building typology with results to **RIBA/ RIAI** standards in the far table. **LETI** metrics:

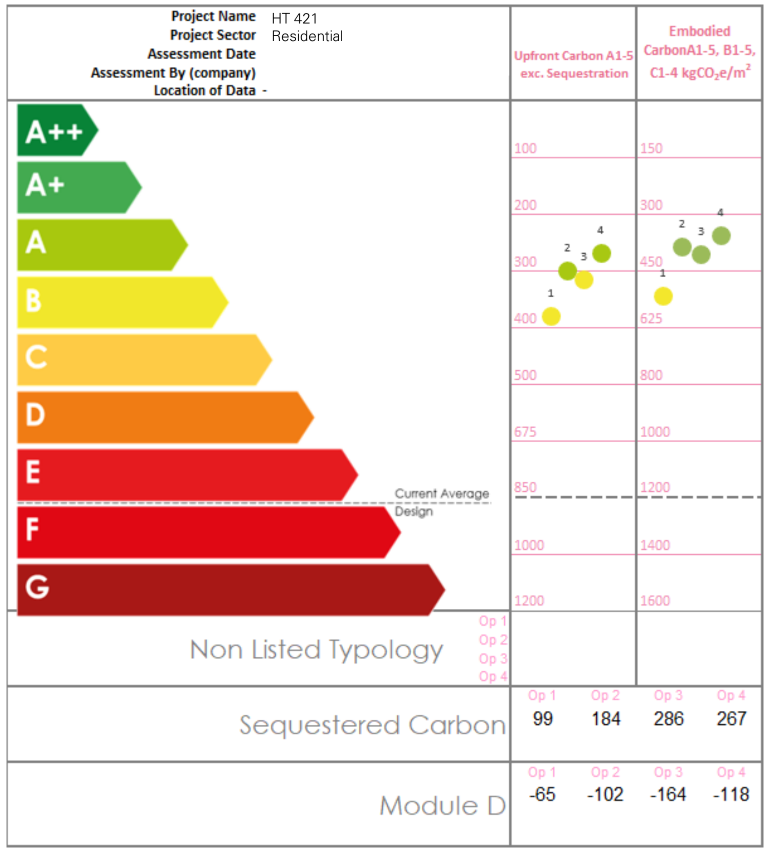
- upfront carbon (A1-5);
- embodied carbon (A1-5, B1-5, C1-4);
- sequestered (biogenic) carbon;
- module D (potential off-site benefits).

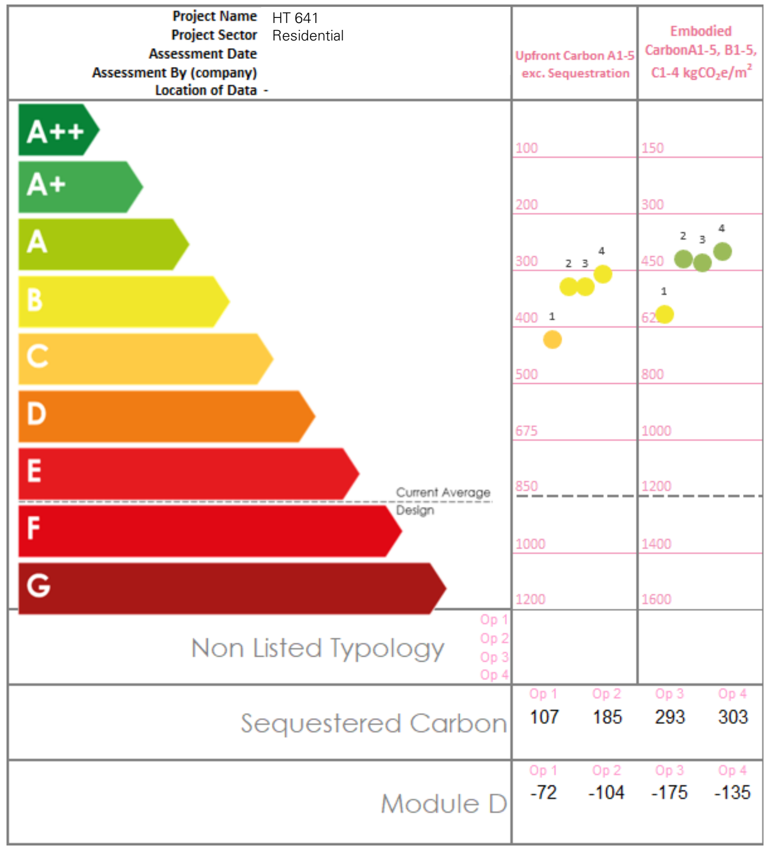
Within the assessment, masonry always results in higher embodied emissions than timber frame options. Reductions of 20-30% are achievable by changing from masonry with PIR to timber frame with mineral wool and PIR. Substituting conventional insulants with biogenic ones can further reduce embodied emissions while sequestering CO_2e within the material.

HT 211 demonstrates at least a 20% reduction in embodied emissions compared to **HT 421** by the **RIBA/ RIAI** lifecycle and **LETI** upfront carbon metrics. The detached **HT 641** increases carbon emissions by 5-50% above **HT 421** and 40-50% above **HT 211**.

Further efficiencies are possible: as demonstrated by the disparity in heating demand between **HT 211** and **HT 421** / **HT 641** a standard specification across typologies is not the most material efficient way of achieving low energy building standards. Apartments and other buildings with good form factor can use a lower fabric specification and still achieve high levels of energy performance. The material efficiencies associated with using less insulation immediately reduces embodied energy.







Headlines for residential typologies

- Higher-density residential buildings deliver lower embodied emissions
- Changing from masonry to timber frame reduces CO_2e by 20-30%
- Timber frame with biogenic insulants can sequester 3-5x as much CO_2e as masonry construction with PIR
- Lower fabric specification for larger buildings/ buildings with better form factor requires less insulation and results in lower embodied emissions

While **LETI** excludes on-roof photovoltaic panels to focus on emissions associated with the building, the impact of on-site generation is a material consideration when assessing embodied energy. This assessment considered identical levels of energy performance for each scenario and therefore requires an identical number of panels to achieve Net Zero: however, as discussed in 2.2.1 Operational, buildings with a higher energy demand will require more on-site renewables to achieve Net Zero. Improved performance also requires less heating infrastructure (smaller heat pumps, fewer/ smaller radiators) which can further reduce embodied emissions and capital cost.

The embodied energy of photovoltaics varies widely but the average for monocrystalline panels is currently 2,560 $kgCO_2e$ per kWp. With a useful lifespan of 25 years, these are renewed twice within the modelled 60 year reference period with additional embodied emissions each time. Fewer panels produce carbon, energy and cost savings for the project life cycle.

Embodied emissions (cradle to grave)		
Option		RIBA/ RIAI
1 Masonry	HT 211	486 $kgCO_2e/m^2$
	HT 421	602 $kgCO_2e/m^2$
	HT 641	748 $kgCO_2e/m^2$
2 Framed	HT 211	389 $kgCO_2e/m^2$
	HT 421	460 $kgCO_2e/m^2$
	HT 641	580 $kgCO_2e/m^2$
3 Timber	HT 211	405 $kgCO_2e/m^2$
	HT 421	480 $kgCO_2e/m^2$
	HT 641	593 $kgCO_2e/m^2$
4 Timber Optimised	HT 211	373 $kgCO_2e/m^2$
	HT 421	429 $kgCO_2e/m^2$
	HT 641	560 $kgCO_2e/m^2$

2.3 Non-Residential

2.3.1 Operational

Modelling of the typologies clearly illustrates that application of standardised fabric specifications is not the most efficient way of delivering buildings to space heating demand and EUI targets: specification can be adjusted to form factor and scale. Specifications were varied considerably between **OF 315** and **SC 1492**, as described in 4: Specifications, while still delivering comparable operational energy performance.

Discussion of the impact of varying specifications on embodied carbon is continued within 2.3.2 Embodied.

In the context of this feasibility study, aligning with the analysed adopted policy by other Local Authorities, Net Zero is achieved by generating as much electricity on-site per annum as the building consumes. The reality is more complex as there are still emissions generated by buildings where photovoltaics meet the annual on-site energy demand. This is a product of the electricity generated by the photovoltaics being imported and exported to and from the grid as not all on-site generation will be immediately utilised.

Operational results are broken down into five separate metrics, tabulated individually for each typology. These were selected to evidence the correlation between thermal performance, operational emissions and the number of photovoltaics required to achieve Net Zero.

The applied metrics are:

- space heating demand;
- energy use intensity (EUI);
- annual energy use per dwelling;
- CO_2e emissions excluding photovoltaics;
- kWp of photovoltaics required to achieve Net Zero.

CO_2e emissions excluding photovoltaics describes the potential emissions if all electricity were imported from the grid. These are the cumulative emissions within a 60 year building lifecycle, applying the 'Falling Short' grid decarbonisation scenario. 5: Building Assessment explores how this is applied and explains the grid decarbonisation scenarios in more detail.

Headlines for non-residential typologies

- Performance of identical buildings is significantly impacted by airtightness, thermal bridging & ventilation > 75% reduction of heating demand possible
- EUI & CO_2e reductions of 30% in upgrading **AD: L (Wales)** to **LETI**
- Lower EUI requires 30% fewer PV panels to achieve 'Net Zero' balance
- Fewer PV panels reduces embodied carbon & capital cost of buildings
- Better form factor/ higher density significantly reduces heating demand

As captured within the result tables, relatively minor improvements to build quality can significantly reduce operational emissions. Upgrading from **AD: L (Wales)** to **LETI** lowers energy use and associated potential emissions by c. 30% across the assessed typologies. 4: Specifications outline the different fabric u-values targeted by the two typologies and provides details of the interventions made to airtightness, thermal bridging and ventilation strategies to uplift energy performance standards.

Diminishing energy demand also requires less on-site generation to achieve Net Zero, reducing the size of photovoltaic arrays by the same c. 30% as EUI drops. Reducing the required number of photovoltaic panels lowers both the associated embodied emissions and the capital cost of the works. Cost implications for the various scenarios will be explored in Work Stage 3F - Cost Viability.

The graphs in 5: Building Assessment demonstrate how EUI is split between space heating, domestic hot water (DHW), auxiliary and household electricity. As the effective performance of the building improves, heating energy reduces from c. 30% of operational energy consumption to c. 5%. Once heating energy is reduced to such a small proportion of the operational demand, further investment should be focused on upgrading appliances and devices to tackle the emissions associated with user energy demand.

EUI and operational emissions must be contextualised with the use of highly efficient ASHPs. As modelled, the specified units deliver heating and hot water at an effective rate of 4.1 kWh of heat for every 1 kWh input of electricity: if heating and hot water were delivered by any other system, associated energy use and resulting emissions would increase c. 400%.

Operational outputs - OF 315					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use	CO_2e emissions ex. PV (60 yrs)	kWp of PV to achieve Net Zero
1 AD: L (Wales) 2025	70.1 kWh/m²/yr	71.1 kWh/m²/yr	22,375 kWh	84.20 tonnes	28.8 kWp
2 AECB CarbonLite	33.3 kWh/m²/yr	66.5 kWh/m²/yr	20,928 kWh	78.80 tonnes	26.8 kWp
3 B&NES	21.4 kWh/m²/yr	57.8 kWh/m²/yr	18,190 kWh	68.40 tonnes	23.2 kWp
4 LETI	10.6 kWh/m²/yr	51.1 kWh/m²/yr	16,081 kWh	60.60 tonnes	21.6 kWp

Operational outputs - SC 1492					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	CO_2e emissions ex. PV (60 yrs)	kWp of PV to achieve Net Zero
1 AD: L (Wales) 2022	56.7 kWh/m²/yr	73.6 kWh/m²/yr	109,811 kWh	345.0 tonnes	141.6 kWp
2 AECB CarbonLite	30.0 kWh/m²/yr	55.3 kWh/m²/yr	82,508 kWh	259.3 tonnes	106.4 kWp
3 B&NES	23.1 kWh/m²/yr	53.7 kWh/m²/yr	80,120 kWh	251.9 tonnes	103.6 kWp
4 LETI	15.1 kWh/m²/yr	52.7 kWh/m²/yr	78,628 kWh	246.8 tonnes	101.6 kWp

2.3.2 Embodied

Modelling of the construction scenarios demonstrates how significant embodied carbon reductions can be achieved by changing what we use to build. Despite the use of different materials, all four scenarios are capable of achieving identical fabric performance and therefore identical operational emissions.

Embodied results to **LETI** standards are represented graphically by individual building typology with results to **RIBA/ RIAI** standards in the far table. **LETI** metrics:

- upfront carbon (A1-5);
- embodied carbon (A1-5, B1-5, C1-4);
- sequestered (biogenic) carbon;
- module D (potential off-site benefits).

Within the assessment, masonry always results in the highest embodied emissions with reductions of 20-30% achievable by changing to a framed structure. Substituting conventional insulants with biogenic ones can reduce embodied emissions a further 15-20% while sequestering CO_2e within the material.

OF 315 presents an anomalous result with unexpected carbon intensity for timber frame with woodfibre by **RIBA/ RIAI** measures. This could be a result of the building form (single level with clerestory roof) but, given the **LETI** assessment does align with the general trend, it is more likely a quirk of what is included and excluded from the applied WLCA measures.

SC 1492 achieves a 35-45% reduction in embodied emissions compared to **OF 315** by **RIBA/ RIAI** and **LETI** upfront carbon metrics. This can be attributed to the efficiencies of densifying development, as the trend established within the assessed residential typologies, complemented by the fabric efficiencies available to the larger building. The lower fabric specification can still achieve high levels of energy performance using significantly less insulation material.

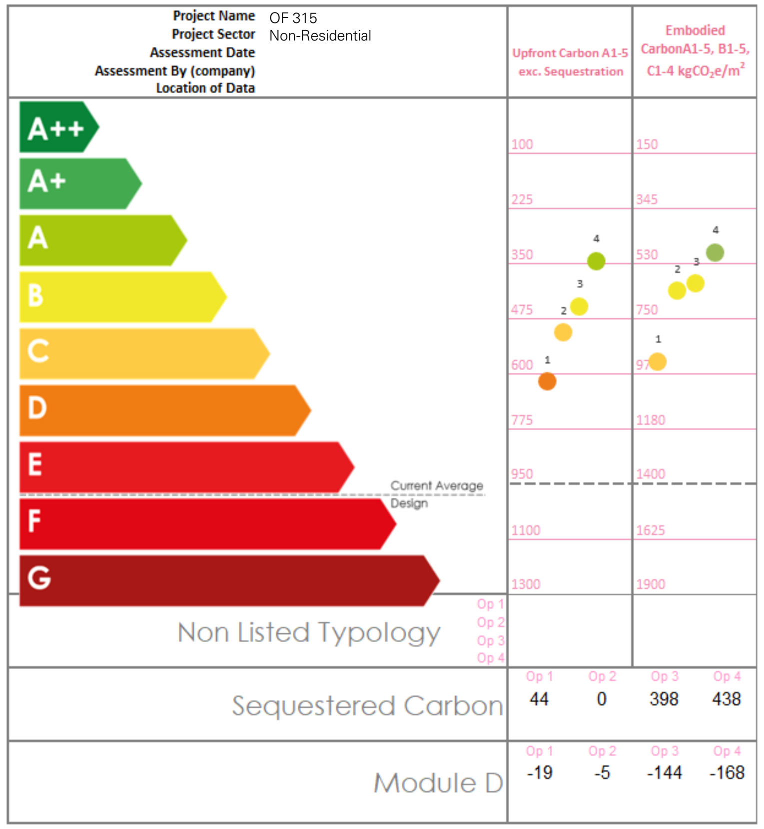
Headlines for non-residential typologies

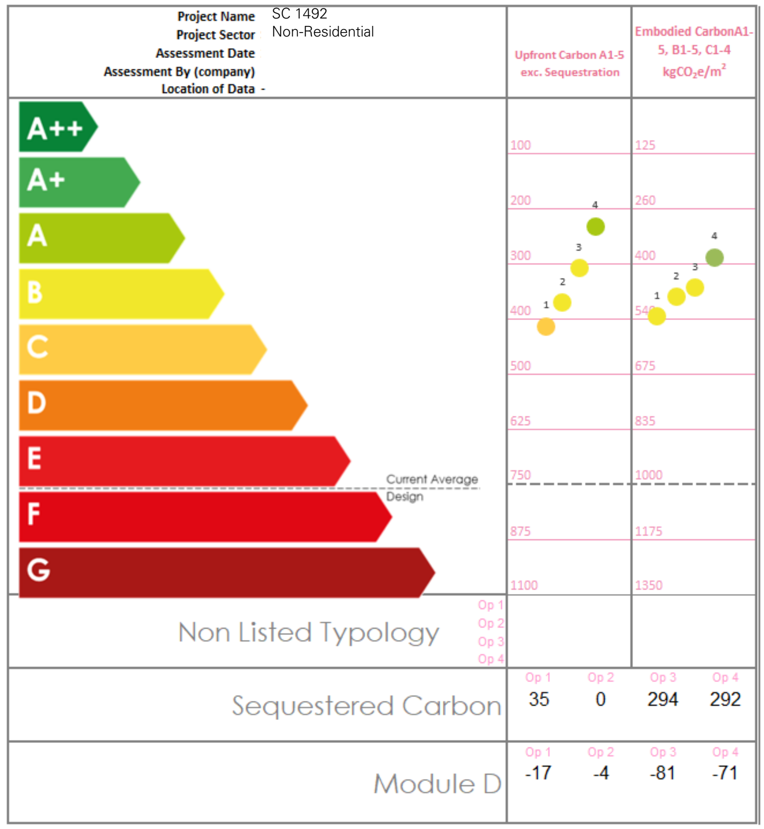
- High-density buildings achieve inherently lower embodied energy
- Changing from masonry to a framed structure reduces CO_2e by 20-30%
- Timber frame with biogenic insulants can sequester 3-5x as much CO_2e as masonry: steel construction has little to no carbon sequestration potential
- Lower fabric specification for larger buildings/ buildings with better form factor requires less insulation and results in lower embodied emissions

While **LETI** excludes on-roof photovoltaic panels to focus on emissions associated with the building, the impact of on-site generation is a material consideration when assessing embodied emissions. This analysis considered identical levels of operational energy performance for each scenario and therefore identical numbers of panels are required to achieve Net Zero: however, as discussed in 2.3.1 Operational, buildings with higher energy demand require more on-site renewables to achieve the Net Zero balance. Improved performance also need smaller and/ or less heating infrastructure (smaller heat pumps, fewer/ smaller radiators) which can contribute to further embodied emission and capital cost savings.

The embodied energy of photovoltaics varies widely but the average for monocrystalline panels is currently 2,560 $kgCO_2$e per kWp. With a useful lifespan of 25 years, these will be renewed twice within the 60 year reference period with additional emissions at each renewal. Installing fewer panels results in carbon, energy and cost savings for the project life cycle.

Material efficiency goes beyond reducing embodied carbon: it also contributes to alleviating the complex issues of social justice and ethics. Particularly in the context of extracting and refining rare earth minerals, there are well-publicised transgressions of human rights and environmental protections. Technologies reliant upon these materials, chiefly renewables such as batteries and photovoltaics, must therefore be used as efficiently as possible in the pursuit of Net Zero and only sourced from those manufacturers who can offer visibility of their supply chains.





Embodied emissions (cradle to grave)		
Option		RIBA/ RIAI
1 Masonry	OF 315	1149 $kgCO_2e/m^2$
	SC 1492	703 $kgCO_2e/m^2$
2 Framed	OF 315	824 $kgCO_2e/m^2$
	SC 1492	654 $kgCO_2e/m^2$
3 Timber	OF 315	1032 $kgCO_2e/m^2$
	SC 1492	631 $kgCO_2e/m^2$
4 Timber Optimised	OF 315	669 $kgCO_2e/m^2$
	SC 1492	553 $kgCO_2e/m^2$

Section 3: Context

3.1 Replacement LDP

The Replacement Local Development Plan 2021-2026: Preferred Strategy (2023) proposes where and how new development will take place over the period to 2036. It outlines potential site allocations for different land uses such as housing and employment and policies to help tackle the declared climate and nature emergencies, safeguard the environment and secure high-quality design. When adopted the RLDP will be used as a basis for determining planning applications.

8,679 dwellings are allocated in order to deliver a housing requirement of 7,890 homes through the plan period with 168 Ha of employment land allocated to enable 67.8 Ha to be brought forward. Conservative GIA estimates translate into 500,000 m²+ of residential development alone.

In February 2020, VoGC signed a Climate Emergency Charter with the Vale Public Services Board setting out the shared commitment to lead by example and take positive action to reduce emissions in the Vale.

Project Zero is VoGC's initial response to the declared climate emergency. Project Zero has brought together a wide range of work and opportunities available to tackle climate change, reduce the Council's carbon emissions to Net Zero by 2030 and encourage others to make positive changes. The climate challenge plan highlights the role of the adopted LDP in contributing to the climate change commitment, for example by securing planning contributions towards sustainable transport schemes and implementation of policies that encourage renewable energy.

Net Zero Carbon Buildings Feasibility Study and Cost Assessment represents the evolution of Project Zero to inform potential policy for the RLDP (pending this feasibility and the following viability assessment). In what Welsh Government have identified as the Decade of Action, and with hundreds of thousands of square metres of development anticipated, Net Zero policy is poised to make significant impact.

3.2 Strategic Sites

The RLDP also identifies the Strategic Growth Area and, within this, five key housing-led sites plus two areas for employment growth. Housing delivery is expected at sites in Barry, Dinas Powys, Rhoose and two sites in St. Athan with Rhoose and St. Athan also expected to deliver employment growth.

Identification of these Strategic Sites is critical to the analysis of the Net Zero Carbon Buildings as it informs the climatic assumptions, including altitude, used for PHPP modelling. The sites share a number of general characteristics: relatively flat agricultural land, generally with tree-lined boundaries, in proximity to the Bristol Channel and at altitudes of no more than 50m.

Within the BRE defined climate region (Severn) this establishes the most appropriate climate data set. It also confirms an altitude of 50m as worst-case for development on the strategic sites: the majority of development is anticipated to be delivered during the life of the RLDP will be at a lower altitude.

All new residential developments will be required to contribute towards the provision of an appropriate mix of market housing, affordable housing, specialist accommodation and support the transition to Net Zero.

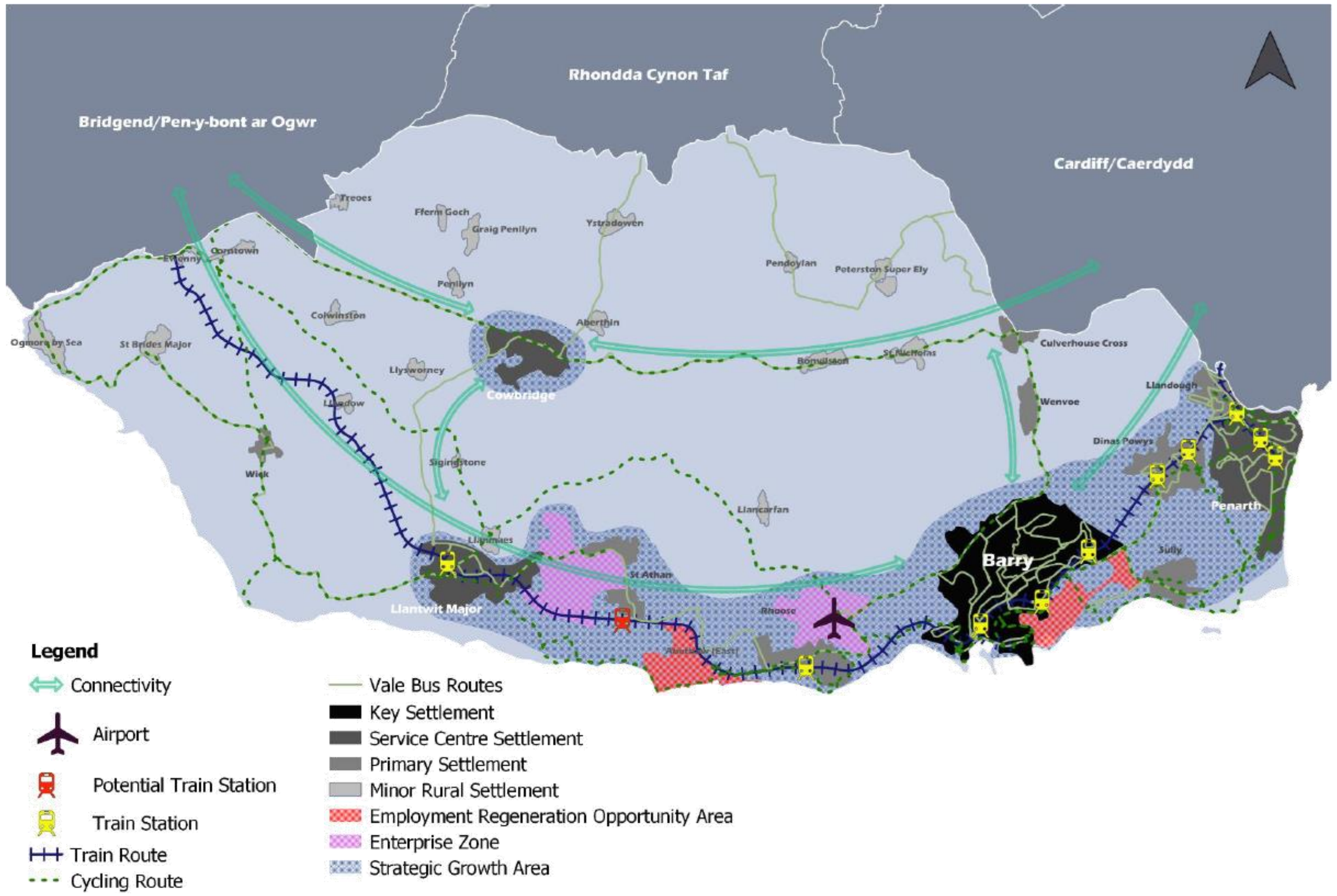


Fig. 02: VoGC's Key Diagram illustrating the extent of the Vale of Glamorgan with the RLDP Strategy, Strategic Growth Area and strategic transport routes overlaid.

3.3 Principles

To reflect the anticipated growth within the RLDP a representative selection of building typologies were identified for modelling. This comprises three residential typologies - HT 211, HT 421 and HT 641 - and two non-residential - OF 315 and SC 1492.

General principles applied to the modelling are to emulate the worst-case scenario and therefore provide conservative guidance on what would be required to achieve the agreed operational standards.

As such, all typologies were modelled facing East-West. Residential typologies were modelled to account for units of the same scale 15.0m from the front elevation and 21.0m from the rear. Non-residential typologies have slightly greater rear offsets to reflect the scale of potential parking courts. For illustrative building drawings and their modelled context refer to 7: Appendices.

East-West orientation is the least favourable for solar gains: in winter it excludes the majority of sunlight, limiting the free heat gains that could otherwise offset space heating demand; in summer it exposes buildings to low angle solar gain that is difficult to control and can exacerbate issues with overheating.

East-West facing roofs have lower generation potential than an equivalent South facing roof. This provides a conservative kWp array sizing. However, East-West oriented photovoltaics can help reduce grid stress as output peaks are different to South-facing arrays.

Distances between buildings are derived from the principles established by Manual for streets (2007). Similar units are positioned to both the East and West to establish horizon shading objects and ensure the assessment remains conservative: unshaded building models would overestimate the potential of solar gains to offset space heating demand.

Section 4: Specifications

4.1 Residential

4.1.1 Operational

Scenario 1: AD: L (Wales) 2025

Building Fabric	
Ground floor	0.110 W/m²K
External wall	0.130 W/m²K
Roof	0.110 W/m²K
Air permeability	5.00 m³/m²/hr
Thermal bridges	0.200 W/mK
Doors & Windows	
Frames U_f	1.400 W/m²K uPVC
Installation TB	0.040 W/mK
Glazing U_g	1.120 W/m²K double low-e glazing 16mm Ar
Glazing g-value	0.64
Glazing edge	0.040 W/mK
Ventilation Strategy	
Ventilation rate	30m³ per person per hour via MEV
Ventilation unit	MEV
HR efficiency	N/A (extract only)
Ducting	
Duct insulation	
Heating	
ASHP	Generic
SCOP	3.30
F-gas	R290
GWP	3
Controls	On/off

AD: L (Wales) 2023 Appendix E currently establishes the minimum performance specification for grant-funded social housing built in Wales. As adoption of the RLDP is anticipated for 2026, it is appropriate to apply projected future scenarios to the modelling process.

In lieu of published details of proposed 2025 revisions, Appendix E has been applied as the baseline building fabric for AD: L (Wales) 2025. This reflects the Welsh Government aspiration to align market and social housing performance requirements.

Scenario 2: AECB CarbonLite

Building Fabric	
Ground floor	0.110 W/m²K
External wall	0.130 W/m²K
Roof	0.110 W/m²K
Air permeability	1.50 m³/m²/hr
Thermal bridges	0.100 W/mK
Doors & Windows	
Frames U_f	0.810-0.850 W/m²K Rehau Artevo
Installation TB	0.040 W/mK
Glazing U_g	1.190 W/m²K double glazing (4w-16Ar-KS4)
Glazing g-value	0.64
Glazing edge	0.025 W/mK
Ventilation Strategy	
Ventilation rate	30m³ per person per hour MVHR
Ventilation unit	EnviroVent energiSava 300
HR efficiency	84%
Ducting	Semi-rigid radial
Duct insulation	50mm closed cell Armaflex
Heating	
ASHP	Vaillant aroTHERM plus
SCOP	4.10
F-gas	R290
GWP	3
Controls	On/off

AECB CarbonLite Building Standard was developed by the Association for Environment Conscious Building (AECB) to apply a less onerous demand-based performance standard than Passivhaus for the UK context. Excepting airtightness and ventilation rate, the values above are not prescribed by the AECB but were developed through the modelling process to ensure the least favourable typology (**HT 641**) could demonstrate compliance with the targeted space heating demand of 40 kWh/m²/yr.

Scenario 3: B&NES

Building Fabric	
Ground floor	0.110 W/m²K
External wall	0.130 W/m²K
Roof	0.110 W/m²K
Air permeability	1.05 m³/m²/hr
Thermal bridges	0.050 W/mK
Doors & Windows	
Frames U_f	0.810-0.850 W/m²K Rehau Artevo
Installation TB	0.040 W/mK
Glazing U_g	0.550 W/m²K double glazing (4-18Ar-4-18Ar4)
Glazing g-value	0.63
Glazing edge	0.025 W/mK
Ventilation Strategy	
Ventilation rate	30m³ per person per hour MVHR
Ventilation unit	EnviroVent energiSava 400
HR efficiency	84%
Ducting	Semi-rigid radial
Duct insulation	50mm closed cell Armaflex
Heating	
ASHP	Vaillant aroTHERM plus
SCOP	4.10
F-gas	R290
GWP	3
Controls	Acc. to ambient temperature

B&NES heating demand and EUI targets reflect the policy aspirations of Bath & North East Somerset. The values above are not prescribed by B&NES but were developed through the modelling process to ensure the least favourable typology (**HT 641**) could demonstrate compliance with the targeted space heating demand of 30 kWh/m²/yr.

Scenario 4: LETI

Building Fabric	
Ground floor	0.110 W/m²K
External wall	0.130 W/m²K
Roof	0.110 W/m²K
Air permeability	0.50 m³/m²/hr
Thermal bridges	-0.050 W/mK
Doors & Windows	
Frames U_f	0.810-0.850 W/m²K Rehau Artevo
Installation TB	0.009-0.023 W/mK
Glazing U_g	0.550 W/m²K double glazing (4-18Ar-4-18Ar4)
Glazing g-value	0.63
Glazing edge	0.025 W/mK
Ventilation Strategy	
Ventilation rate	30m³ per person per hour MVHR
Ventilation unit	Zehnder ComfoAir 225
HR efficiency	92%
Ducting	Semi-rigid radial
Duct insulation	50mm closed cell Armaflex
Heating	
ASHP	Vaillant aroTHERM plus
SCOP	4.10
F-gas	R290
GWP	3
Controls	Acc. to ambient temperature

LETI performance standards were developed by the Low Energy Transformation Initiative (LETI), formerly the London Energy Transformation Initiative, as net zero building standards that apply demand-based performance targets. Excepting ventilation rate, the values above are not prescribed by LETI but were developed through the modelling process to ensure the least favourable typology (**HT 641**) could demonstrate compliance with the targeted space heating demand of 15 kWh/m²/yr.

4.1.2 Embodied

Scenario 1: Masonry (Masonry with PIR)

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Sand & cement screed on 500 gauge polythene	65
PIR insulation	200
Concrete slab on 1200 gauge polythene DPM	150
External Walls	
Plasterboard w/ skim	15
Battens to form service zone	38x47
Passive Purple Internal Vapour Control Paint	
Forterra Evalast aggregate block	100
PIR insulation w/ joints taped	165
Ventilated cavity + brickwork	50+103
Party Walls	
Sand & cement plaster	13
Blockwork	100
Cavity fully filled w/ ROCKWOOL	50
Blockwork	100
Sand & cement plaster finish	13
Internal Walls	
Wet plaster finish	15
Blockwork	100
Wet plaster finish	15
Intermediate Floor	
Chipboard floor finish	22
SJL45 STEICOjoist w/ ROCKWOOL (100mm)	300
Plasterboard w/ skim	12.5
Separating Floor	
Sand & cement screed	65
Damp proof membrane	0.2
REGUPOL sonus curve 8* resilient layer	
Prestressed concrete beams w/ 50mm topping	150
Suspended ceiling w/ ROCKWOOL (50mm)	200
Plasterboard w/ skim	12.5
Roof	
Plasterboard w/ skim	15
Battened service zone over 500 gauge VCL	38x47
Attic trusses w/ ROCKWOOL Insulation Roll	400
Ventilated attic	
Concrete tiles	

Scenario 2: Framed (140mm Stud Mineral Wool & PIR)

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Sand & cement screed on 500 gauge polythene	65
XPS insulation on 1200 gauge DPM	250
Concrete beam w/ Thermalite FLOORBLOCK	150
External Walls	
Plasterboard w/ skim	15
Battens to form service zone	38x47
PIR insulation	80
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber stud filled w/ Isover Frame Roll 32	140
Panelvent sheathing board	12
Ventilated cavity + brickwork	50+103
Party Walls	
Plasterboard (12.5x2) w/ skim finish	25
Timber stud filled w/ ISOVER Frame Roll 32	89
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Cavity fully filled w/ ISOVER Frame Roll 32	50
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber stud filled w/ ISOVER Frame Roll 32	89
Plasterboard (12.5x2) wi/ skim finish	25
Internal Walls	
Plasterboard w/ skim finish	12.5
Timber stud w/ ISOVER Frame Roll 32 (50mm)	89
Plasterboard w/ skim finish	12.5
Intermediate Floor	
Chipboard floor finish	22
SJL45 STEICOjoist with ROCKWOOL (100mm)	300
Plasterboard w/ skim	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m³)	18
253mm web joist w/ mineral wool (100mm)	253
Resilient bar (16mm) w/ plasterboard (2x15mm)	16+30
Suspended ceiling + plasterboard	150+15
Roof	
Plasterboard w/ skim	15
Battened service zone over 500 gauge VCL	38x47
Attic trusses w/ KNAUF Earthwool Loft Roll	400
Ventilated attic	
Clay tiles	

Scenario 3: Timber (140mm Stud Woodfibre)

Construction	Size (mm)
Ground Floor	
Concrete raft on 500 gauge polythene	150
Jackon ATLAS XPS raft formwork	280
External Walls	
Plasterboard w/ skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber stud filled w/ Gutex Thermofibre	140
Gutex Mulitherm	160
Ventilated cavity + brickwork	50+103
Party Walls	
Plasterboard (12.5x2) w/ skim finish	25
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber stud filled w/ Warmcel + OSB sheathing	89+9
Cavity fully filled w/ Warmcel	60
Timber stud filled w/ Warmcel + OSB sheathing	89+9
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Plasterboard (12.5x2) w/ skim finish	25
Internal Walls	
Plasterboard w/ skim finish	12.5
Timber stud w/ Gutex Thermofibre	89
Plasterboard w/ skim finish	12.5
Intermediate Floor	
Chipboard floor finish	22
SJL45 STEICOjoist w/ Gutex Thermofibre	300
Plasterboard w/ skim	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m³)	18
253mm web joist w/ mineral wool (100mm)	253
Resilient bar (16mm) w/ plasterboard (2x15mm)	16+30
Suspended ceiling + plasterboard	150+15
Roof	
Plasterboard w/ skim	15
Battened service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Attic trusses w/ IndiTherm Hemp Flexibatt	400
Ventilated attic	
Spanish slate	

Scenario 4: Timber Optimised (Twin Stud Cellulose)

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Chipboard floor finish	22
SJL45 STEICOjoist filled w/ Warmcel	390
External Walls	
Plasterboard with skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber stud filled w/ Warmcel	292
Panelvent sheathing board	12
Ventilated cavity + brickwork	50+103
Party Walls	
Plasterboard (12.5x2) w/ skim finish	25
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber stud filled w/ Warmcel + OSB sheathing	89+9
Cavity fully filled w/ Warmcel	60
Timber stud filled w/ Warmcel + OSB sheathing	89+9
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Plasterboard (12.5x2) w/ skim finish	25
Internal Walls	
Plasterboard with skim finish	12.5
Timber stud filled w/ Warmcel	89
Plasterboard with skim finish	12.5
Intermediate Floor	
Chipboard floor finish	22
SJL45 STEICOjoist w/ Warmcel (100mm)	300
Plasterboard w/ skim	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m³)	18
253mm web joist w/ mineral wool (100mm)	253
Resilient bar (16mm) w/ plasterboard (2x15mm)	16+30
Suspended ceiling + plasterboard	150+15
Roof	
Plasterboard w/ skim	15
Battened service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Attic trusses w/ Warmcel cellulose insulation	315
Ventilated attic	
Welsh slate	

spring design

4.2 Non-Residential

4.2.1 Operational

Scenario 1: AD: L (Wales)

Building Fabric	
Ground floor	**2025** 0.110 W/m^{2}K **2022** 0.220 W/m^{2}K
External wall	**2025** 0.130 W/m^{2}K **2022** 0.260 W/m^{2}K
Roof	**2025** 0.110 W/m^{2}K **2022** 0.200 W/m^{2}K
Air permeability	5.00 m^3/m^2/hr
Thermal bridges	0.200 W/mK
Doors & Windows	
Frames U_f	1.400 W/m^{2}K uPVC
Installation TB	0.040 W/mK
Glazing U_g	1.120 W/m^{2}K double low-e glazing 16mm Ar
Glazing g-value	0.64
Glazing edge	0.040 W/mK
Ventilation Strategy	
Ventilation rate	20m^3 per person per hour via MEV
Ventilation unit	MEV
HR efficiency	N/A (extract only)
Ducting	
Duct insulation	
Heating	
ASHP	Generic
SCOP	3.30
F-gas	R290
GWP	3
Controls	On/off

OF 315 applies the Appendix E fabric specification as an uplift beyond that required by AD: L (Wales) 2022 for non-residential development. Prior to publication of AD: L (Wales) 2025, it is considered appropriate to assume fabric standards will improve to these levels.

SC 1492, due to its scale and the resulting efficiencies to the form factor, applies the limiting u-values defined in AD: L (Wales) 2022 for the floor, walls and roof.

By varying u-values it is possible to demonstrate how better factor (a lower ratio of external surface area to internal volume) can more efficiently use materials to achieve the same energy standards.

Scenario 2: AECB CarbonLite

Building Fabric	
Ground floor	**2025** 0.110 W/m^{2}K **2022** 0.220 W/m^{2}K
External wall	**2025** 0.130 W/m^{2}K **2022** 0.260 W/m^{2}K
Roof	**2025** 0.110 W/m^{2}K **2022** 0.200 W/m^{2}K
Air permeability	1.50 m^3/m^2/hr
Thermal bridges	0.100 W/mK
Doors & Windows	
Frames U_f	0.810-0.850 W/m^{2}K Rehau Artevo
Installation TB	0.040 W/mK
Glazing U_g	1.190 W/m^{2}K double glazing (4w-16Ar-KS4)
Glazing g-value	0.64
Glazing edge	0.025 W/mK
Ventilation Strategy	
Ventilation rate	20m^3 per person per hour MVHR
Ventilation unit	EnviroVent energiSava 300
HR efficiency	84%
Ducting	Semi-rigid radial
Duct insulation	50mm closed cell Armaflex
Heating	
ASHP	Vaillant aroTHERM plus
SCOP	4.10
F-gas	R290
GWP	3
Controls	On/off

AECB CarbonLite Building Standard was developed by the Association for Environment Conscious Building (AECB) to apply a less onerous demand-based performance standard than Passivhaus for the UK context. Excepting airtightness and ventilation rate, the values above are not prescribed by the AECB but were developed through the modelling process to ensure the least favourable typology (**OF 315**) could demonstrate compliance with the targeted space heating demand of 40 kWh//m^2/yr.

Scenario 3: B&NES

Building Fabric	
Ground floor	**2025** 0.110 W/m^{2}K **2022** 0.220 W/m^{2}K
External wall	**2025** 0.130 W/m^{2}K **2022** 0.260 W/m^{2}K
Roof	**2025** 0.110 W/m^{2}K **2022** 0.200 W/m^{2}K
Air permeability	1.50 m^3/m^2/hr
Thermal bridges	0.050 W/mK
Doors & Windows	
Frames U_f	0.810-0.850 W/m^{2}K Rehau Artevo
Installation TB	0.040 W/mK
Glazing U_g	0.550 W/m^{2}K double glazing (4-18Ar-4-18Ar4)
Glazing g-value	0.63
Glazing edge	0.025 W/mK
Ventilation Strategy	
Ventilation rate	20m^3 per person per hour MVHR
Ventilation unit	EnviroVent energiSava 400
HR efficiency	84%
Ducting	Semi-rigid radial
Duct insulation	50mm closed cell Armaflex
Heating	
ASHP	Vaillant aroTHERM plus
SCOP	4.10
F-gas	R290
GWP	3
Controls	Acc. to ambient temperature

B&NES heating demand targets reflect the policy aspirations of Bath & North East Somerset for residential development which, combined with the LETI EUI target, offers a useful comparator along the spectrum of low energy building performance. The values above are not prescribed by B&NES but were developed through the modelling process to ensure the least favourable typology (**OF 315**) could demonstrate compliance with the targeted space heating demand of 30 kWh//m^2/yr.

Scenario 4: LETI

Building Fabric	
Ground floor	**2025** 0.110 W/m^{2}K **2022** 0.220 W/m^{2}K
External wall	**2025** 0.130 W/m^{2}K **2022** 0.260 W/m^{2}K
Roof	**2025** 0.110 W/m^{2}K **2022** 0.200 W/m^{2}K
Air permeability	0.50 m^3/m^2/hr
Thermal bridges	-0.050 W/mK
Doors & Windows	
Frames U_f	0.810-0.850 W/m^{2}K Rehau Artevo
Installation TB	0.009-0.023 W/mK
Glazing U_g	0.550 W/m^{2}K double glazing (4-18Ar-4-18Ar4)
Glazing g-value	0.63
Glazing edge	0.025 W/mK
Ventilation Strategy	
Ventilation rate	20m^3 per person per hour MVHR
Ventilation unit	Zehnder ComfoAir 225
HR efficiency	92%
Ducting	Semi-rigid radial
Duct insulation	50mm closed cell Armaflex
Heating	
ASHP	Vaillant aroTHERM plus
SCOP	4.10
F-gas	R290
GWP	3
Controls	Acc. to ambient temperature

LETI performance standards were developed by the Low Energy Transformation Initiative (LETI), formerly the London Energy Transformation Initiative, as net zero building standards that apply demand-based performance targets. Excepting ventilation rate, the values below are not prescribed by LETI but were developed through the modelling process to ensure the least favourable typology (**OF 315**) could demonstrate compliance with the targeted space heating demand of 15 kWh//m^2/yr.

4.2.2 Embodied OF 315

Scenario 1: Masonry (Masonry with PIR)

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Sand & cement screed on 500 gauge polythene	65
PIR insulation	200
Concrete slab on 1200 gauge polythene DPM	150
External Walls	
Plasterboard w/ skim	15
Battens to form service zone	38x47
Passive Purple Internal Vapour Control Paint	
Forterra Evalast aggregate block	100
PIR insulation w/ joints taped	165
Ventilated cavity + brickwork	50+103
Internal Walls	
Wet plaster finish	15
Blockwork	100
Wet plaster finish	15
Separating Floor	
Sand & cement screed	65
Damp proof membrane	0.2
REGUPOL sonus curve 8* resilient layer	
Prestressed concrete beams w/ 50mm topping	150
Suspended ceiling w/ ROCKWOOL (50mm)	200
Plasterboard w/ skim	12.5
Roof	
Suspended ceiling + plasterboard	150+15
Steel rafters with intumescent paint	
Z-purlins	140
OSB3	18
Rockwool HARDROCK Multi-Fix	320
Battens to form ventilation zone	47x38
Standing seam w/ breather membrane on OSB3	9
Additional Structure	
Steel posts & beams	

Scenario 2: Framed (Steel Frame with PIR Panels)

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Sand & cement screed on 500 gauge polythene	65
XPS insulation on 1200 gauge DPM	250
Concrete beam w/ Thermalite FLOORBLOCK	150
External Walls	
Plasterboard (12.5x2) w/ skim	15
Primary steel frame with intumescent paint	
Z-purlins	140
Kingspan QuadCore AWP Supreme Wall Panel	150
Internal Walls	
Plasterboard w/ skim finish	15
Gypframe 70 S 50 'C' Studs	70
partially filled w/ ISOVER APR 1200	50
Plasterboard w/ skim finish	15
Separating Floor	
Cellecta Screedboard 30	30
Cast in-situ concrete (100mm) in metal deck	150
Suspended ceiling w/ ROCKWOOL (25mm)	200
Plasterboard with skim	15
Roof	
Suspended ceiling + plasterboard	150+15
Steel rafters with intumescent paint	
Z-purlins	140
Kingspan QuadCore KS1000RW	150
Additional Structure	
Steel posts & beams	

Scenario 3: Timber (Timber Stud Woodfibre)

Construction	Size (mm)
Ground Floor	
Concrete raft on 500 gauge polythene	150
Jackon ATLAS XPS raft formwork	280
External Walls	
Plasterboard w/ skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber stud filled w/ Gutex Thermofibre	140
Gutex Mulitherm	160
Battens to form ventilation zone	47x38
Rockpanel cladding	9
Internal Walls	
Plasterboard w/ skim finish	12.5
Timber stud w/ Gutex Thermofibre	89
Plasterboard w/ skim finish	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m³)	18
253mm web joist w/ mineral wool (100mm)	253
Resilient bar (16mm) w/ plasterboard (2x15mm)	16+30
Suspended ceiling + plasterboard	150+15
Roof	
Plasterboard w/ skim	15
Battened service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber I-joists w/ Gutex Thermofibre	315
Panelvent sheathing board	12
Battens to form ventilation zone	47x38
Standing seam w/ breather membrane on OSB3	9
Additional Structure	
LVL posts & beams	

Scenario 4: Timber Optimised (Twin Stud Cellulose)

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Chipboard floor finish	22
SJL45 STEICOjoist filled w/ Warmcel	390
External Walls	
Plasterboard with skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber stud filled w/ Warmcel	292
Panelvent sheathing board	12
Battens to form ventilation zone	47x38
Rockpanel cladding	9
Internal Walls	
Plasterboard with skim finish	12.5
Timber stud filled w/ Warmcel	89
Plasterboard with skim finish	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m³)	18
253mm web joist w/ mineral wool (100mm)	253
Resilient bar (16mm) w/ plasterboard (2x15mm)	16+30
Suspended ceiling + plasterboard	150+15
Roof	
Plasterboard w/ skim	15
Battened service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber I-joists w/ Warmcel cellulose insulation	315
Panelvent sheathing board	12
Battens to form ventilation zone	47x38
Standing seam w/ breather membrane on OSB3	9
Additional Structure	
Glulam posts & beams	

4.2.2 Embodied SC 1492

Scenario 1: Masonry (Masonry with PIR)

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Sand & cement screed on 500 gauge polythene	65
PIR insulation	100
Concrete slab on 1200 gauge polythene DPM	150
External Walls	
Plasterboard w/ skim	15
Battens to form service zone	38x47
Passive Purple Internal Vapour Control Paint	
Forterra Evalast aggregate block	100
PIR insulation w/ joints taped	75
Ventilated cavity + brickwork	50+103
Internal Walls	
Wet plaster finish	15
Blockwork	100
Wet plaster finish	15
Separating Floor	
Sand & cement screed	65
Damp proof membrane	0.2
REGUPOL sonus curve 8* resilient layer	
Prestressed concrete beams w/ 50mm topping	150
Suspended ceiling w/ ROCKWOOL (50mm)	200
Plasterboard w/ skim	12.5
Roof	
Suspended ceiling + plasterboard	150+15
Steel rafters with intumescent paint	
Z-purlins	140
OSB3	18
Rockwool HARDROCK Multi-Fix	185
Battens to form ventilation zone	47x38
Standing seam w/ breather membrane on OSB3	9
Additional Structure	
Steel posts & beams	

Scenario 2: Framed (Steel Frame with PIR Panels)

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Sand & cement screed on 500 gauge polythene	65
XPS insulation on 1200 gauge DPM	115
Concrete beam w/ Thermalite FLOORBLOCK	150
External Walls	
Plasterboard (12.5x2) w/ skim	15
Primary steel frame with intumescent paint	
Z-purlins	140
Kingspan QuadCore AWP Supreme Wall Panel	70
Internal Walls	
Plasterboard w/ skim finish	15
Gypframe 70 S 50 'C' Studs	70
partially filled w/ ISOVER APR 1200	50
Plasterboard w/ skim finish	15
Separating Floor	
Cellecta Screedboard 30	30
Cast in-situ concrete (100mm) in metal deck	150
Suspended ceiling w/ ROCKWOOL (25mm)	200
Plasterboard with skim	15
Roof	
Suspended ceiling + plasterboard	150+15
Steel rafters with intumescent paint	
Z-purlins	140
Kingspan QuadCore KS1000RW	85
Additional Structure	
Steel posts & beams	

Scenario 3: Timber (Timber Stud Woodfibre)

Construction	Size (mm)
Ground Floor	
Concrete raft on 500 gauge polythene	150
Jackon ATLAS XPS raft formwork	135
External Walls	
Plasterboard w/ skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber stud filled w/ Gutex Thermofibre	140
Gutex Mulitherm	20
Battens to form ventilation zone	47x38
Rockpanel cladding	9
Internal Walls	
Plasterboard w/ skim finish	12.5
Timber stud w/ Gutex Thermofibre	89
Plasterboard w/ skim finish	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m³)	18
253mm web joist w/ mineral wool (100mm)	253
Resilient bar (16mm) w/ plasterboard (2x15mm)	16+30
Suspended ceiling + plasterboard	150+15
Roof	
Plasterboard w/ skim	15
Battened service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber I-joists w/ Gutex Thermofibre (168mm)	315
Panelvent sheathing board	12
Battens to form ventilation zone	47x38
Standing seam w/ breather membrane on OSB3	9
Additional Structure	
LVL posts & beams	

Scenario 4: Timber Optimised (Twin Stud Cellulose)

Construction	Size (mm)
Foundations	
Concrete trench fill	600x600
Ground Floor	
Chipboard floor finish	22
SJL45 STEICOjoist w/ Warmcel (60mm)	350
External Walls	
Plasterboard with skim	15
Battens to form service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber stud filled w/ Warmcel	130
Panelvent sheathing board	12
Battens to form ventilation zone	47x38
Rockpanel cladding	9
Internal Walls	
Plasterboard with skim finish	12.5
Timber stud filled w/ Warmcel	89
Plasterboard with skim finish	12.5
Separating Floor	
Cellecta Screedboard 28	28
OSB deck (min. 600kg/m³)	18
253mm web joist w/ mineral wool (100mm)	253
Resilient bar (16mm) w/ plasterboard (2x15mm)	16+30
Suspended ceiling + plasterboard	150+15
Roof	
Plasterboard w/ skim	15
Battened service zone	38x47
SMARTPLY ProPassiv OSB (airtightness & VCL)	12.5
Timber I-joists w/ Warmcel (163mm)	315
Panelvent sheathing board	12
Battens to form ventilation zone	47x38
Standing seam w/ breather membrane on OSB3	9
Additional Structure	
Glulam posts & beams	

Section 5: Building Assessment

5.1 Assessment Methodologies

5.1.1 Operational

Whole Life Carbon Assessment (WLCA) is undertaken and reported by JB Sustainable Building Consultancy in accordance with the internationally recognised RICS methodology which is based on EN 15978 and used by RIBA, LETI, CIBSE and IStructE. This WLCA standard provides a detailed methodology to enable consistent measurement and quantification of whole life carbon emissions, inclusive of all embodied and operational carbon throughout the whole life cycle of a building.

Whole life carbon assessment for the built environment 2nd edition (2023) requires operational energy use predictions to be completed by a suitably qualified professional using the guidance outlined either in CIBSE's TM54, NABERS, ASHRAE Standard 90.1 or the Passivhaus Planning Package (PHPP). Approved Document L 2021/ 2022 calculations using the SAP methodology are explicitly forbidden: these are not considered to be either an appropriate or accurate prediction of energy consumption.

All modelling has been undertaken in the Passivhaus Planning Package (PHPP), an Excel-based design tool introduced in 1998 and subjected to continual refinement since. PHPP is produced by the Passivhaus Institute and aimed for use by architects, engineers and other building designers to determine compliance with the spectrum of low energy building standards.

The reliability of these calculations has been established over the last twenty-five years and tens of thousands of built projects. Extensive post-occupancy evaluation and scientific analysis of completed projects in various climates has compared operational heating demand with the calculated outputs and demonstrated high levels of correlation between PHPP calculations and the in-use performance of buildings. This proves that an appropriate understanding of building physics in building design, accompanied by quality control on site, can eliminate the performance gap.

PHPP considers a wide range of variables which affect heat loss, energy use and internal comfort, allowing for a superior fit between predicted energy use and real-world performance. Detailed modelling results in outputs that can be used to assess and optimise the latent efficiency of building proposals.

Operational emissions are derived from regulated and unregulated energy use as calculated by PHPP. Operational carbon from electricity primarily uses National Grid's Falling Short energy scenario (slowest electricity grid decarbonisation) with reducing emissions over time to avoid underestimating operational carbon. If the rate of grid decarbonisation increases then calculated operational carbon emissions would reduce accordingly.

Manual alignments undertaken to upgrade from RICS WLCA 1st edition to 2nd edition:

- imported electricity: impact of energy generation and distribution infrastructure embodied carbon added;
- exported and re-imported PV generation: added transport and distribution emissions plus the impact of energy distribution infrastructure embodied carbon;
- PV generated and utilised on-site has no emissions and directly offsets grid imports;
- assumed percentages used on-site or exported and reimported based on RICS WLCA 2nd edition;
- operational water use based on 110L per occupant per day using PHPP occupancy. UK Government GHG reporting factors used with 90% of supplied water assumed to be discharged as waste water.

RICS WLCA 2nd edition decarbonisation factors have been added to all of above so imported electricity uses National Grid's Future Energy Scenarios (2023) Falling Short scenario reflecting the slowest decarbonisation of the grid. Other operational energy measures are appropriately decarbonised.

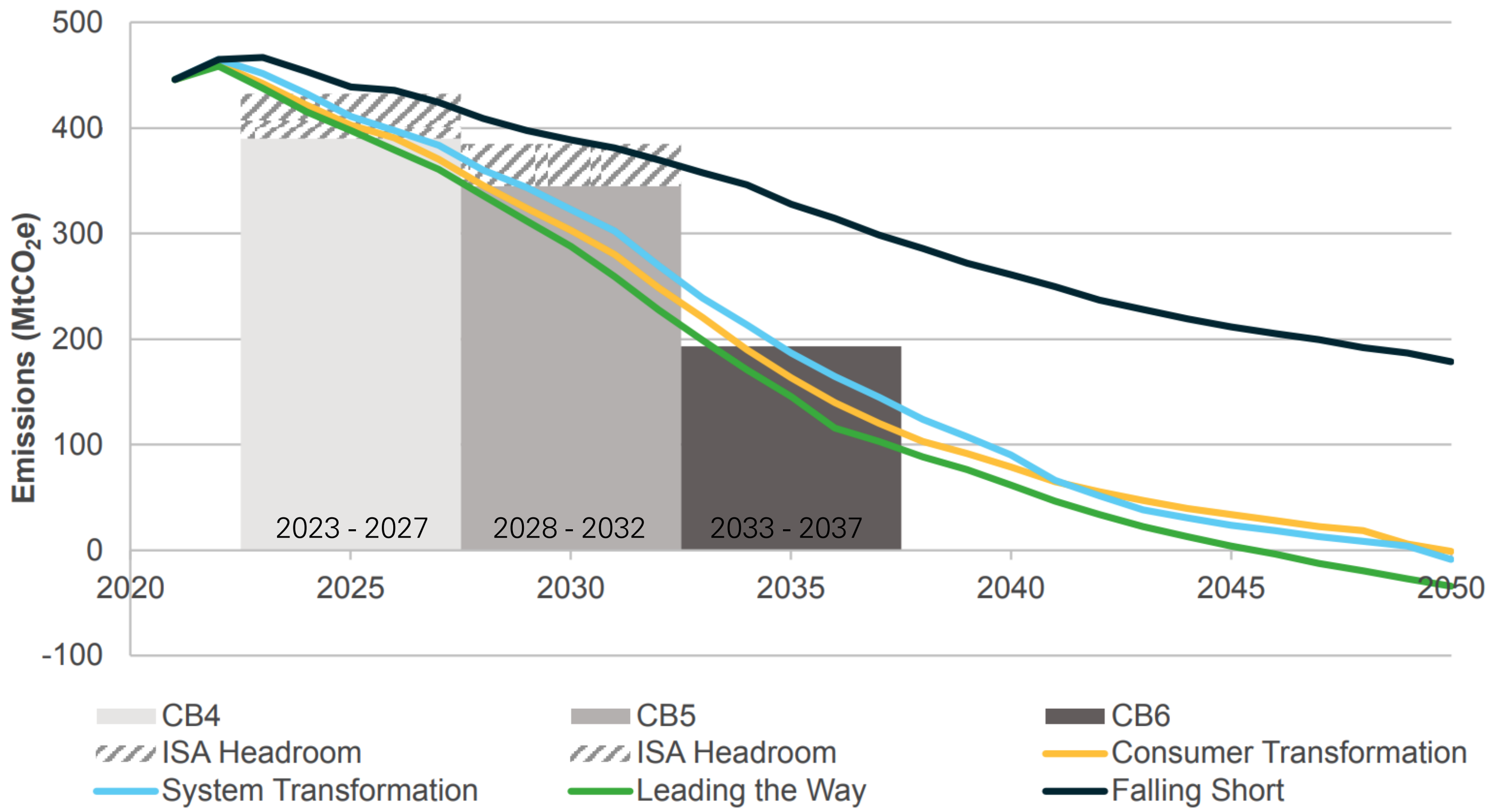


Fig. 03: Total net greenhouse gas emissions including carbon budgets, National Grid Future Energy Scenarios 2023

The above graph illustrates four decarbonisation scenarios for the UK grid with CB*X* = Carbon Budgets and ISA (sic) = International Aviation and Shipping.

Leading the Way reaches net zero by 2046 and achieves annual net emissions of -34 $MtCO_2e$ by 2050 which amounts to removal of Greenhouse Gas (GHG) emissions from the atmosphere.

Consumer Transformation and System Transformation reach net zero by 2050. Falling Short - the scenario applied by RICS WLCA 2nd edition methodology - does not achieve net zero by 2050 and results in 179 Mt of residual CO_2e emissions.

Net zero power sector emissions are reached in 2034 for both scenarios Leading the Way and Consumer Transformation: one year earlier than the target of 2035. System Transformation reaches net zero power sector emissions by 2035 and Falling Short in 2046.

How the grid ultimately decarbonises is not a matter VoGC can control. However, policy should reduce grid demand and contribute to renewable generation.

As stated within 4: Specifications the modelled scenarios employ air source heat pumps (ASHPs) with a seasonal coefficient of performance (SCOP) of 4.10.

This SCOP translates into every 1 kWh of electricity delivered into the unit being converted into 4.1 kWh of useful heat (whether for space heating or hot water). If heating and hot water were delivered by any other system, associated energy use and resulting CO_2e emissions would increase by at least 400%. As such, EUI and operational emissions must be recognised as significantly lower than would be possible with the use of any other heat source.

5.1.2 Embodied

Operational emissions can achieve net zero if low operational energy demand is paired with sufficient on-site generation. The same accounting methods are not used in Whole Life Carbon Assessment (WLCA) as sequestered (biogenic) carbon is not discounted from construction-related emissions, recognising this will be released at the end of a building's useful life. Net zero embodied carbon is therefore not feasible: it is more productive to promote low carbon construction.

The lifecycle considered by the RICS methodology is 60 years. It is hoped that all buildings will remain in use for significantly longer but standardised lifespans enables comparison of projects on the same terms. Replacement of products and materials over the life of the building is included, based on product lifespans on Environmental Product Declarations (EPDs).

WLCA requires consideration of Modules A-D with the system boundary for an asset's lifecycle (A-C) plus the off-site benefits that can be derived (D), e.g. if building components could be used elsewhere or electricity generated by on-site renewables or water treated on-site was exported for use elsewhere. Module D must be reported separately and not aggregated with A-C.

Due to the project timeline, WLCA was completed to 1st edition principles with some elements manually aligned to the 2nd edition. This was necessary due to the publication of Whole life carbon assessment for the built environment 2nd edition in September 2023 for adoption on 1 July 2024: WLCA tools have not yet integrated updates to fully adopt 2nd edition principles.

These manual alignments can be summarised as:

- material wastage percentages derived from RICS WLCA 2nd edition but impacts are not separated into A5.4 emissions and are instead included as part of the quantity of each material;
- A5.2 construction process emissions updated to the standard assumption of 40 $kgCO_2/m^2$ GIA;
- C1 demolition emissions updated to 25% of A5.2.

Assessment here is broadly equivalent to technical design stage assessment under RICS WLCA 2nd edition for benchmarking purposes. Ideally transport distances would be based on calculated distance for each material and supplier, but as this cannot be known with certainty at this stage, they are based on the standard defaults for RICS WLCA 1st edition.

Transportation distances are defined as:

- local 50km;
- national 350km;
- Europe 1550km;
- World 10250 km.

The 2nd edition adds increased granularity of local and regional transportation which has not been implemented due to the unknowns described above.

RICS WLCA 2nd Edition requires a decarbonised and non-carbonised assessment to be carried out. The approach taken here is closer to the RICS WLCA 1st edition in that a single scenario has been modelled for each typology and version. This applies decarbonised electricity emissions factors based on the National Grid Future Energy Scenarios 'Falling Short' scenario which has the slowest predicted rate of decarbonisation. The decarbonisation is applied to all energy impacts and to the carbon emissions associated with water use.

RICS WLCA 2nd edition additionally requires the decarbonised scenario to assume a reduction in emissions of product replacements during the building lifecycle, assuming manufacturing processes will continue to decarbonise. This is not implemented in this analysis due to the complexity of doing so within current tools which have not yet been updated to the 2nd edition methodology. Items requiring renewal within the reference period are therefore modelled with the original embodied carbon profile.

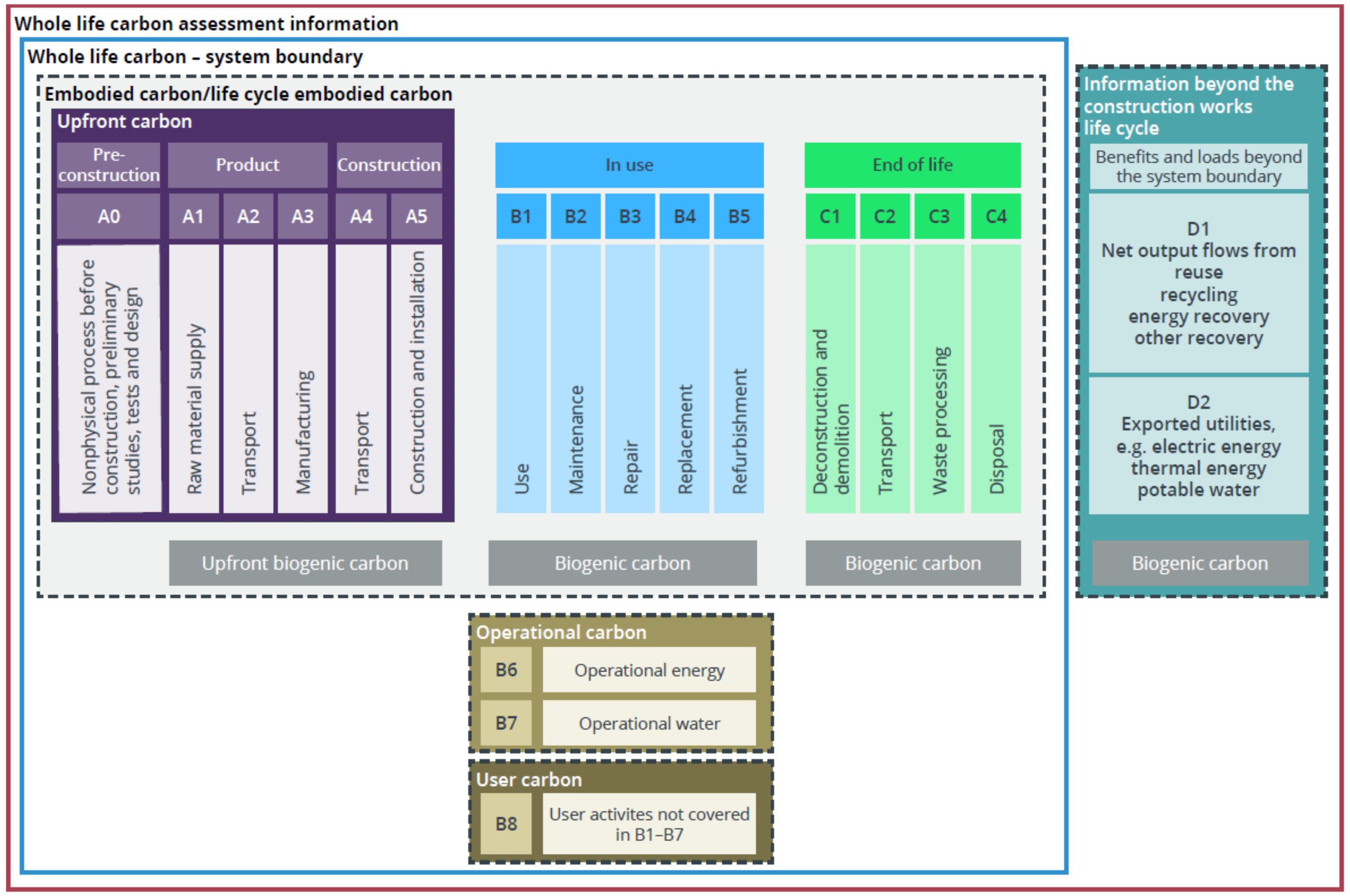


Fig. 04: Building life cycle stages and information modules with additions to illustrate sequestered biogenic carbon, RICS Whole life carbon assessment for the built environment 2nd edition 2023

As earlier commentary, material and product lifespans are based on EPD/ manufacturer data or RICS defaults. Construction to lower energy standards necessarily brings an increased attention to weatherproof and airtight detailing which has been found to increase the lifespan of some products and indeed whole buildings. This potential lengthening of lifespans is not accounted for to provide conservative estimates of the carbon improvements: in reality, further embodied reductions would be likely with the most energy efficient options.

Some material quantities may be overestimated, e.g. where external dimensions were used to calculate the quantities of external walls. In realty the layers of wall closest to the inside will have smaller areas. The standard material wastage factors in RICS WLCA 2nd edition have nonetheless been applied to all entries.

WLCA results are presented to RIBA/ RIAI and LETI reporting standards. RIBA/ RIAI quotes whole-life emissions (cradle-to-grave) with LETI split between upfront carbon (cradle-to-gate), embodied carbon, sequestered carbon and Module D benefits.

Section 5: Building Assessment

5.2 Residential

5.2.1 HT 211

This section contains the quantitative assessment of HT 211. For illustrative drawings of the building and its modelled context, please refer to 7: Appendices.

Operational outputs demonstrate the benefits of form factor and the efficiencies of density: space heating demand reduces more than 90% from AD: L (Wales) 2025 to LETI operational scenarios. This results in an almost 40% reduction in EUI, potential CO_2e emissions and the number of photovoltaics required to achieve Net Zero.

Installing photovoltaics on every roof slope in every orientation, approximately 99 panels could be accommodated on the building. Assuming 400W panels this translates into a potential 39.6 kWp array: 36 kWp is the minimum for AD: L (Wales) 2025 with 10 photovoltaic panels per dwelling.

Being so close to capacity significantly limits the articulation of the building by constraining the design of the roofscape. The roof form could not change from pitched to flat (without a separately framed system) or the gables hipped without reducing potential panel numbers; similarly, dormers and rooflights cannot be introduced without impacting the size of the array.

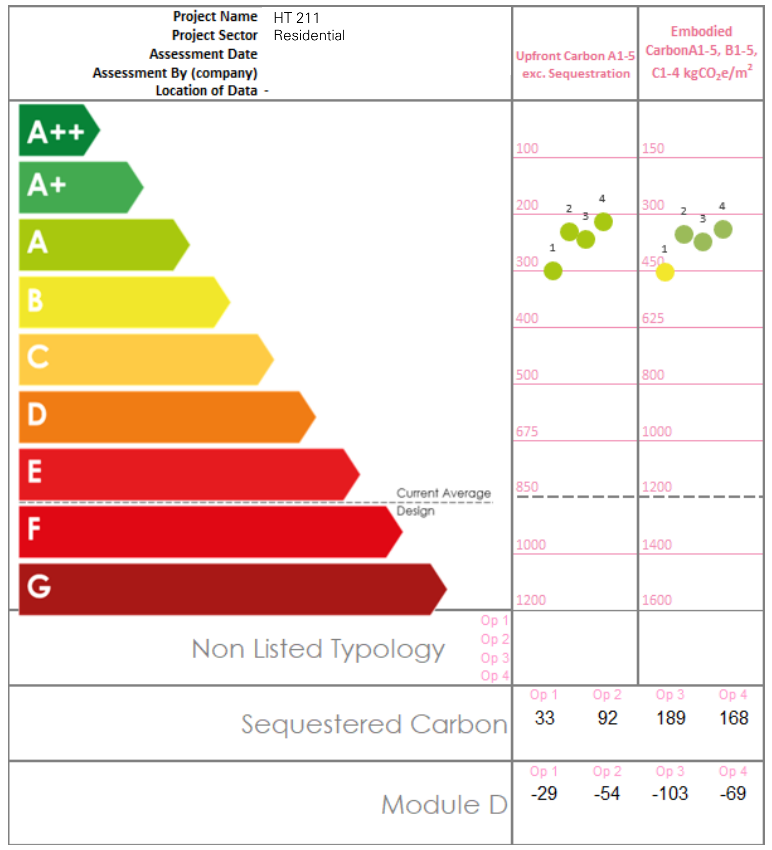
The above commentary applies to the current three storey proposals. Attempting to densify with additional storeys could generate operational and embodied efficiencies: however, it would increase the number of photovoltaics required to be installed on the roof. This demonstrates that attempting to achieve Net Zero without addressing energy demand constrains design opportunities and actively inhibits densification.

As previously discussed, this typology illustrates that applying a standard specification is not the most material efficient way of achieving low energy building standards. Apartments and other buildings with good

Operational outputs					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	CO_2e emissions ex. PV (60 yrs)	kWp of PV to Net Zero per dwelling
1 AD: L (Wales) 2025	60.7 kWh/m²/yr	44.9 kWh/m²/yr	2,686 kWh/yr	10.10 tonnes	4.0 kWp
2 AECB CarbonLite	19.7 kWh/m²/yr	37.5 kWh/m²/yr	2,244 kWh/yr	8.53 tonnes	2.9 kWp
3 B&NES	13.4 kWh/m²/yr	33.0 kWh/m²/yr	1,974 kWh/yr	7.49 tonnes	2.5 kWp
4 LETI	3.9 kWh/m²/yr	28.5 kWh/m²/yr	1,705 kWh	6.44 tonnes	2.4 kWp

Embodied outputs					
		LETI			
Option	RIBA/ RIAI (cradle to grave)	Upfront carbon A1-5	Embodied carbon A1-5, B1-5, C1-4	Sequestered carbon	Module D (offsite benefits)
1 Masonry	486 $kgCO_2e/m^2$	298 $kgCO_2e/m^2$	457 $kgCO_2e/m^2$	33 $kgCO_2e/m^2$	-29 $kgCO_2e/m^2$
2 Framed	389 $kgCO_2e/m^2$	234 $kgCO_2e/m^2$	359 $kgCO_2e/m^2$	92 $kgCO_2e/m^2$	-54 $kgCO_2e/m^2$
3 Timber	405 $kgCO_2e/m^2$	242 $kgCO_2e/m^2$	376 $kgCO_2e/m^2$	189 $kgCO_2e/m^2$	-103 $kgCO_2e/m^2$
4 Timber Optimised	373 $kgCO_2e/m^2$	212 $kgCO_2e/m^2$	343 $kgCO_2e/m^2$	168 $kgCO_2e/m^2$	-69 $kgCO_2e/m^2$

LETI embodied carbon reporting - HT 211



Headlines for HT 211

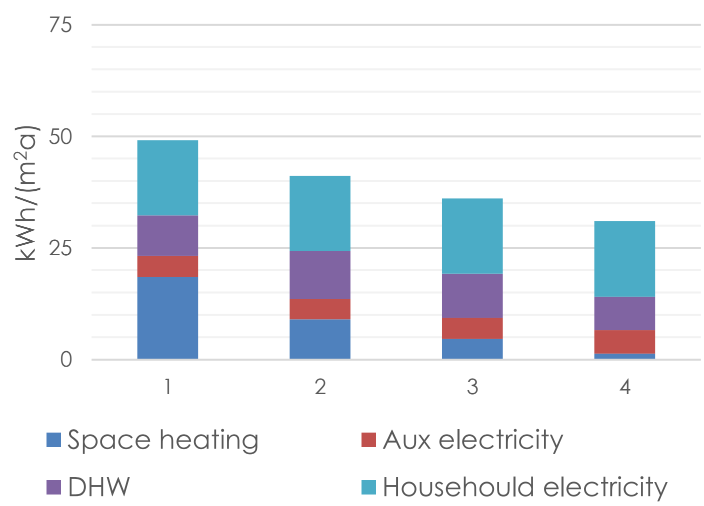
- EUI & CO_2e reductions of 40% in upgrading **AD: L (Wales) 2025** to **LETI**
- Fabric specification could lower and still achieve the highest operational standards, lowering embodied energy
- PV provisions for **AD: L (Wales) 2025** max-out the potential of the roofscape
- Timber reduces embodied carbon by 20% vs. masonry with PIR & cellulose insulation sequesters 5x more CO_2e

form factor can use a lower fabric specification and still achieve high performance levels. Reducing the fabric specification - the quantity of insulation - could achieve further reductions to the calculated embodied energy.

Embodied outputs and the colour-coded LETI diagram demonstrate the relative carbon intensities of the modelled construction scenarios. Excluding internal finishes and fittings, all scenarios achieve both the RIBA/ RIAI 2030 and LETI 2030 targets. Twin Stud Cellulose (Scenario 4) delivers the lowest carbon intensity, prioritising short-term rotation and recycled biogenic materials, with 5x more carbon sequestered than the equivalent masonry construction. Detailed embodied information is diagrammed on page 16.

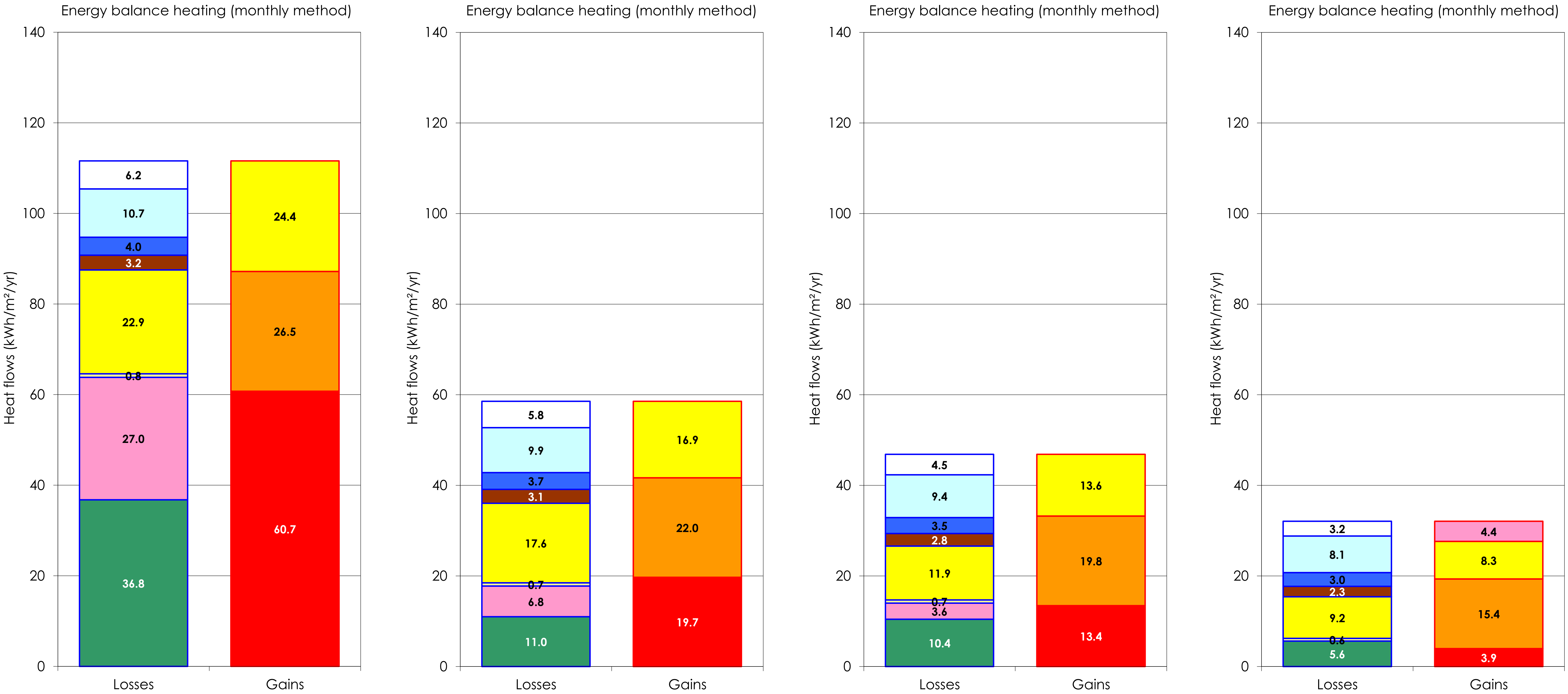
Energy consumption by use opposite shows how use is split between heating, domestic hot water, auxiliary electricity and household electricity.

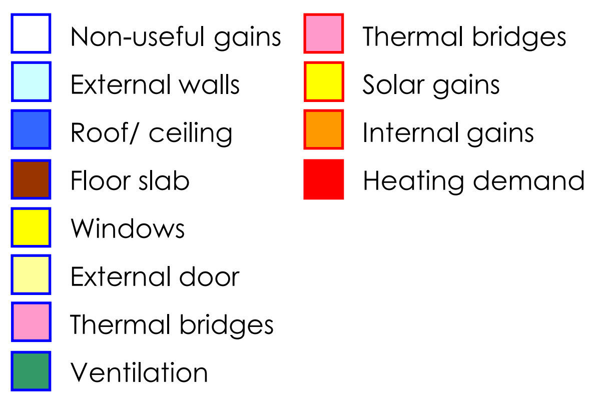
Energy consumption by use - HT 211



Operational Scenarios

HT 211 - AD: L (Wales) 2025 | HT 211 - AECB CarbonLite | HT 211 - B&NES | HT 211 - LETI





This page contains the energy balance from PHPP for the four energy scenarios. These graphical outputs illustrate where both heat losses and gains - which must be balanced to maintain a stable, comfortable internal temperature - occur: this information can be used to interrogate the performance of the building fabric and optimise specifications.

Annual energy bills calculated by multiplying EUI by Ofgem Q2 2024 electricity unit rate of £0.245 per kWh

Projected Annual Electricity Bills

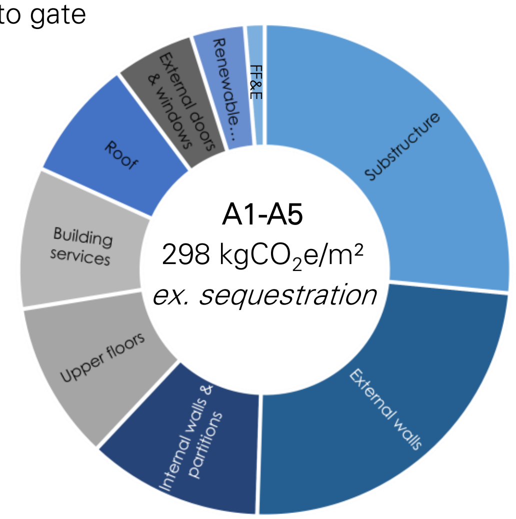
- AD:L (Wales) 2025 £658.07
- AECB CarbonLite £549.78
- B&NES £483.63
- LETI £417.73

excludes standing charge & PV offsets

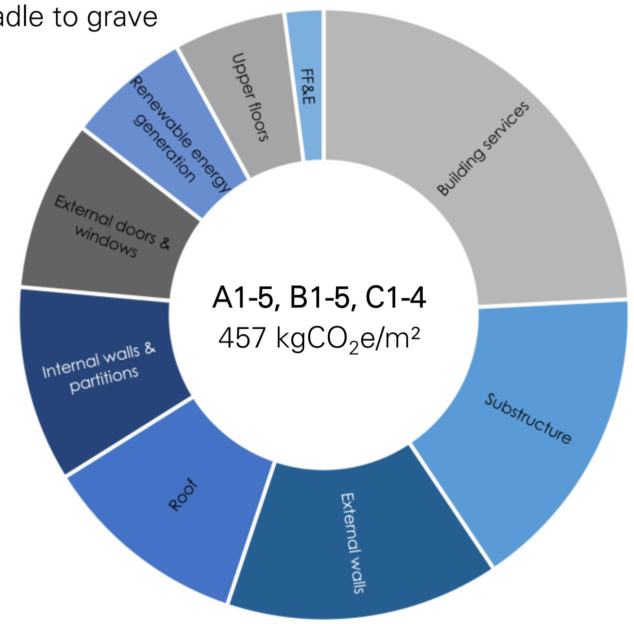
Embodied Scenarios

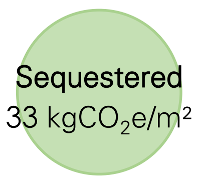
HT 211 - Scenario 1
BUA: Masonry with PIR
diagrams exclude groundworks

Cradle to gate



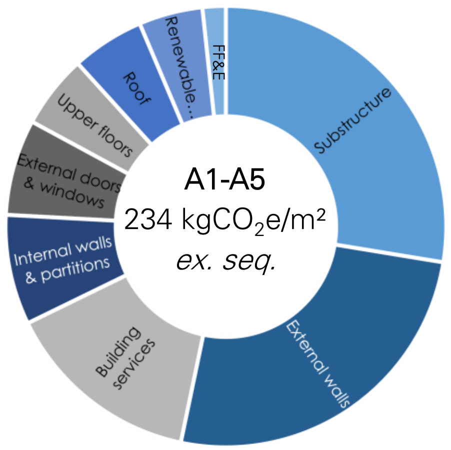
Cradle to grave



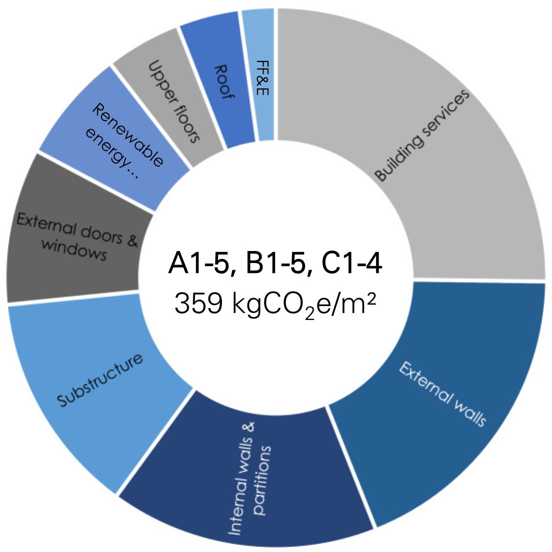


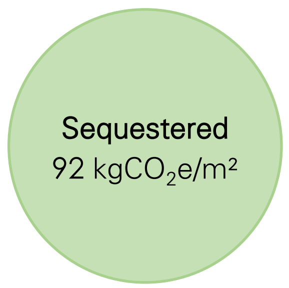
HT 211 - Scenario 2
Framed: 140mm Stud Mineral Wool & PIR
diagrams exclude groundworks

Cradle to gate



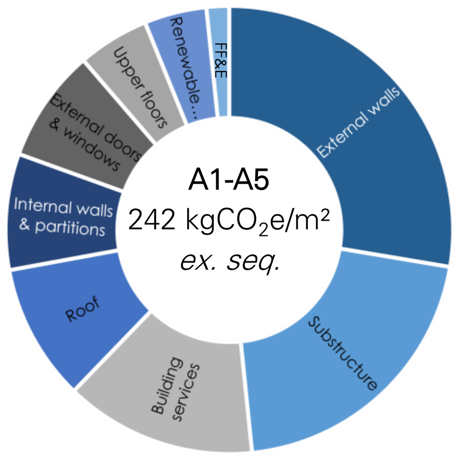
Cradle to grave



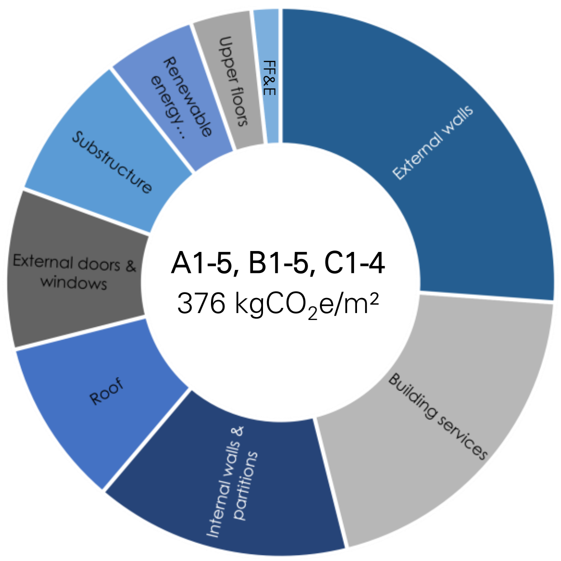


HT 211 - Scenario 3
Timber: 140mm Stud Woodfibre
diagrams exclude groundworks

Cradle to gate

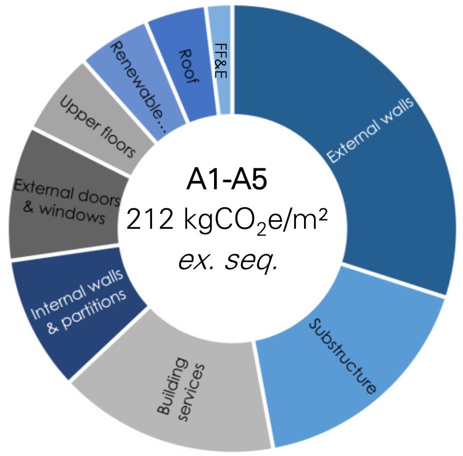


Cradle to grave

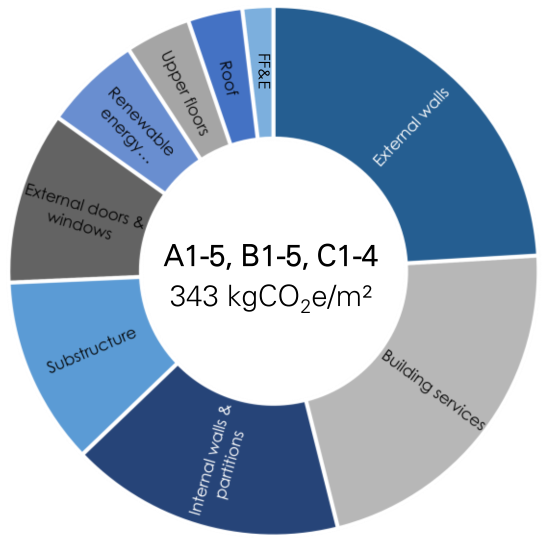


HT 211 - Scenario 4
Timber Optimised: Twin Stud Cellulose
diagrams exclude groundworks

Cradle to gate



Cradle to grave



5.2.2 HT 421

This section contains the quantitative assessment of **HT 421**. For illustrative drawings of the buildings and the modelled context, please refer to 7: Appendices.

Operational outputs demonstrate the potential to reduce space heating demand more than 80% by improving from AD: L (Wales) 2025 to LETI operational scenarios. This results in a 35% reduction in EUI, potential CO_2e emissions and the number of photovoltaics required to achieve Net Zero.

Installing panels on both roof slopes accommodates a maximum 30 panels per dwelling. Assuming 400W panels this translates into a potential 12 kWp array. While there is some headroom between maximum capacity and the requirements of AD: L (Wales) 2025 to reach Net Zero a South-facing dwelling could not host the full array on the South roof slope.

As with **HT 211 CA** the roof cannot vary substantially: the pitch cannot be flattened or the gables hipped without reducing the potential number of panels; the introduction of dormers and rooflights would also reduce the size of the array. Reduction of heating demand should be the priority to allow flexibility in the design of the roof and facilitate the potential for an additional storey if densification is required.

Embodied outputs and the colour-coded LETI diagram demonstrate the relative carbon intensities of the modelled construction scenarios. Excluding internal finishes and fittings, all timber scenarios achieve both the RIBA/ RIAI 2030 and LETI 2030 targets: Masonry with PIR (Scenario 1) meets the RIBA/ RIAI 2030 target of 625 $kgCO_2e/m^2$ but exceeds the LETI 2030 upfront target by more than 25%.

Twin Stud Cellulose (Scenario 4) delivers the lowest carbon intensity, prioritising short-term rotation and recycled biogenic materials, reducing upfront carbon 10% more than other timber options and 30% more than masonry with 2.7x more carbon sequestered. For this typology the sequestered carbon of Twin Stud Cellulose exceeds the upfront carbon emissions.

Detailed embodied information is diagrammed on page 22. Acknowledging future production processes are not modelled as decarbonised as would be correct in RICS WLCA 2[nd] edition, it is worth noting the relative emissions associated with maintaining a 4.8 kWp array for the 60 year reference period.

Energy consumption by use opposite shows how use is split between heating, domestic hot water, auxiliary electricity and household electricity: the modelled variables only impact energy associated with heating. This demonstrates how space heating can reduce from 40% to under 10% of the total energy use with the minor fabric interventions proposed.

Operational outputs - HT 421

Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	CO_2e emissions ex. PV (60 yrs)	kWp of PV to Net Zero per dwelling
1 AD: L (Wales) 2025	87.1 kWh/m²/yr	62.5 kWh/m²/yr	5,200 kWh	19.75 tonnes	7.6 kWp
2 AECB CarbonLite	36.7 kWh/m²/yr	43.8 kWh/m²/yr	3.644 kWh	13.95 tonnes	5.4 kWp
3 B&NES	28.3 kWh/m²/yr	41.8 kWh/m²/yr	3,478 kWh	13.30 tonnes	5.0 kWp
4 LETI	14.3 kWh/m²/yr	40.0 kWh/m²/yr	3,328 kWh	12.75 tonnes	4.8 kWp

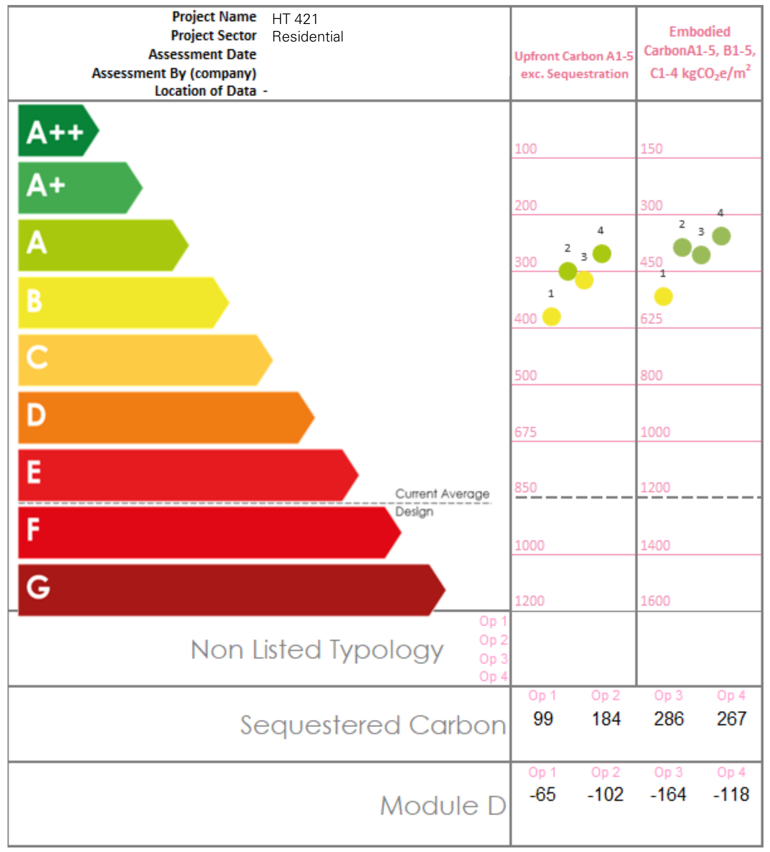
Embodied outputs - HT 421

Option	RIBA/ RIAI (cradle to grave)	LETI			
		Upfront carbon A1-5	Embodied carbon A1-5, B1-5, C1-4	Sequestered carbon	Module D (offsite benefits)
1 Masonry	602 $kgCO_2e/m^2$	378 $kgCO_2e/m^2$	531 $kgCO_2e/m^2$	99 $kgCO_2e/m^2$	-67 $kgCO_2e/m^2$
2 Framed	460 $kgCO_2e/m^2$	300 $kgCO_2e/m^2$	390 $kgCO_2e/m^2$	184 $kgCO_2e/m^2$	-104 $kgCO_2e/m^2$
3 Timber	480 $kgCO_2e/m^2$	314 $kgCO_2e/m^2$	410 $kgCO_2e/m^2$	286 $kgCO_2e/m^2$	-166 $kgCO_2e/m^2$
4 Timber Optimised	429 $kgCO_2e/m^2$	266 $kgCO_2e/m^2$	359 $kgCO_2e/m^2$	267 $kgCO_2e/m^2$	-118 $kgCO_2e/m^2$

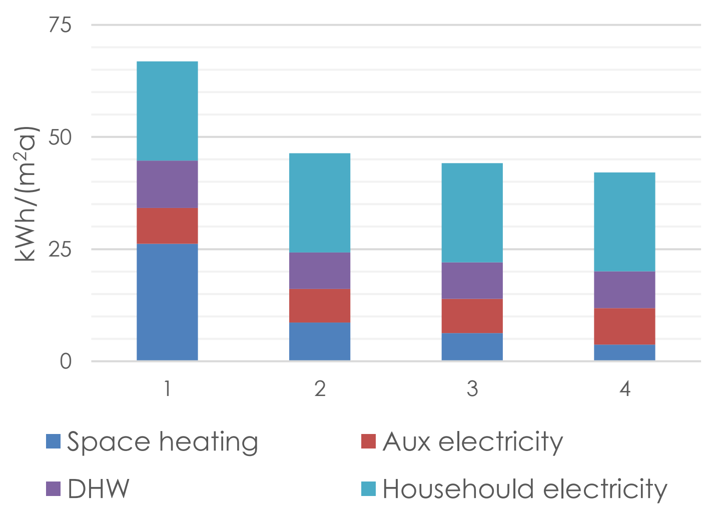
Headlines for HT 421

- EUI & CO_2e reductions of 35% in upgrading **AD: L (Wales) 2025** to **LETI**
- PV provisions for **AD: L (Wales) 2025** do not fit on a single roof slope
- Timber reduces embodied carbon by 20% vs. masonry with PIR & cellulose insulation sequesters 2.7x more CO_2e
- Timber with cellulose insulation has sequestered carbon exceeding upfront embodied emissions

LETI embodied carbon reporting - HT 421

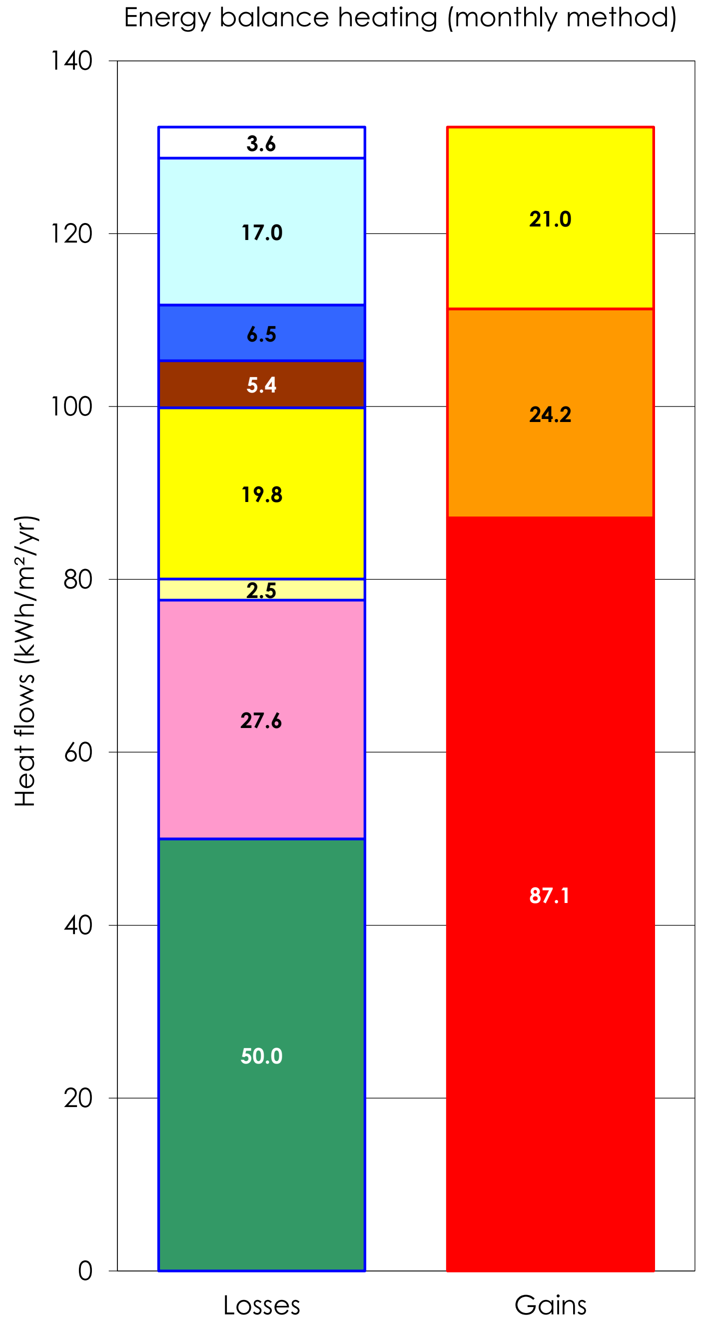


Energy consumption by use - HT 421

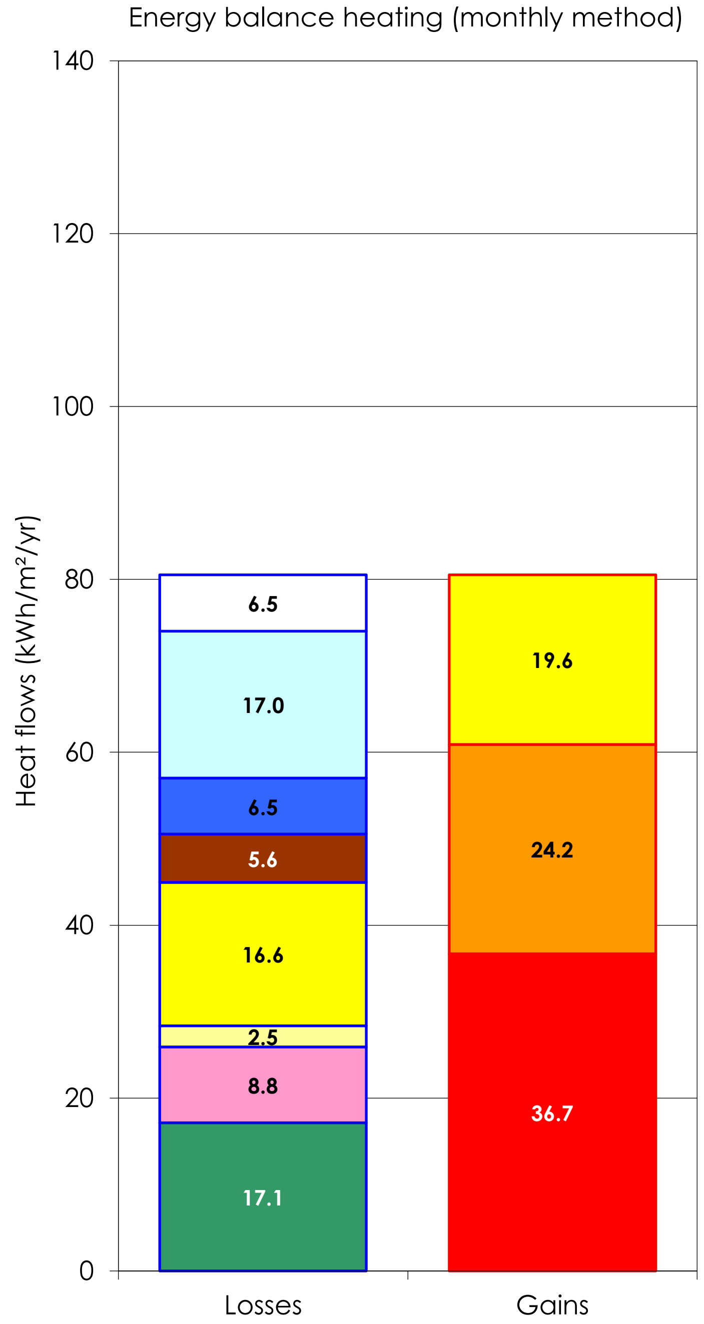


Operational Scenarios

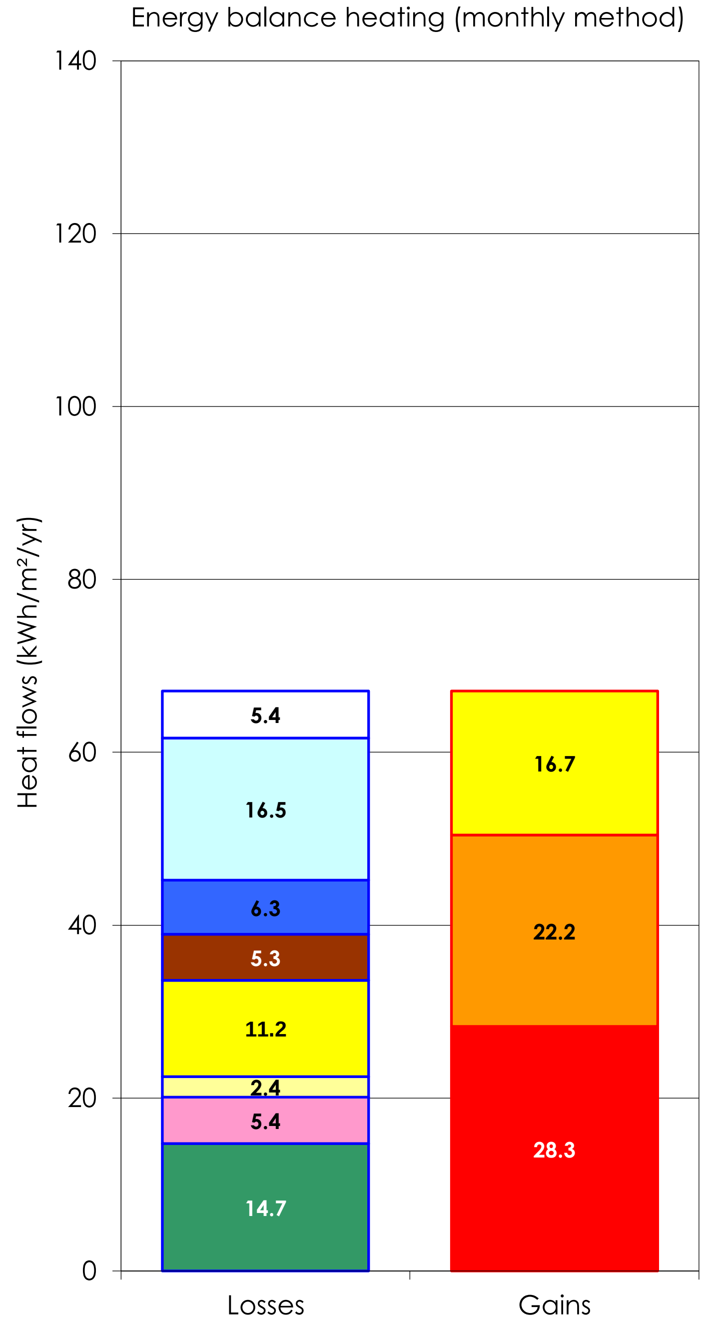
HT 421 - AD: L (Wales) 2025



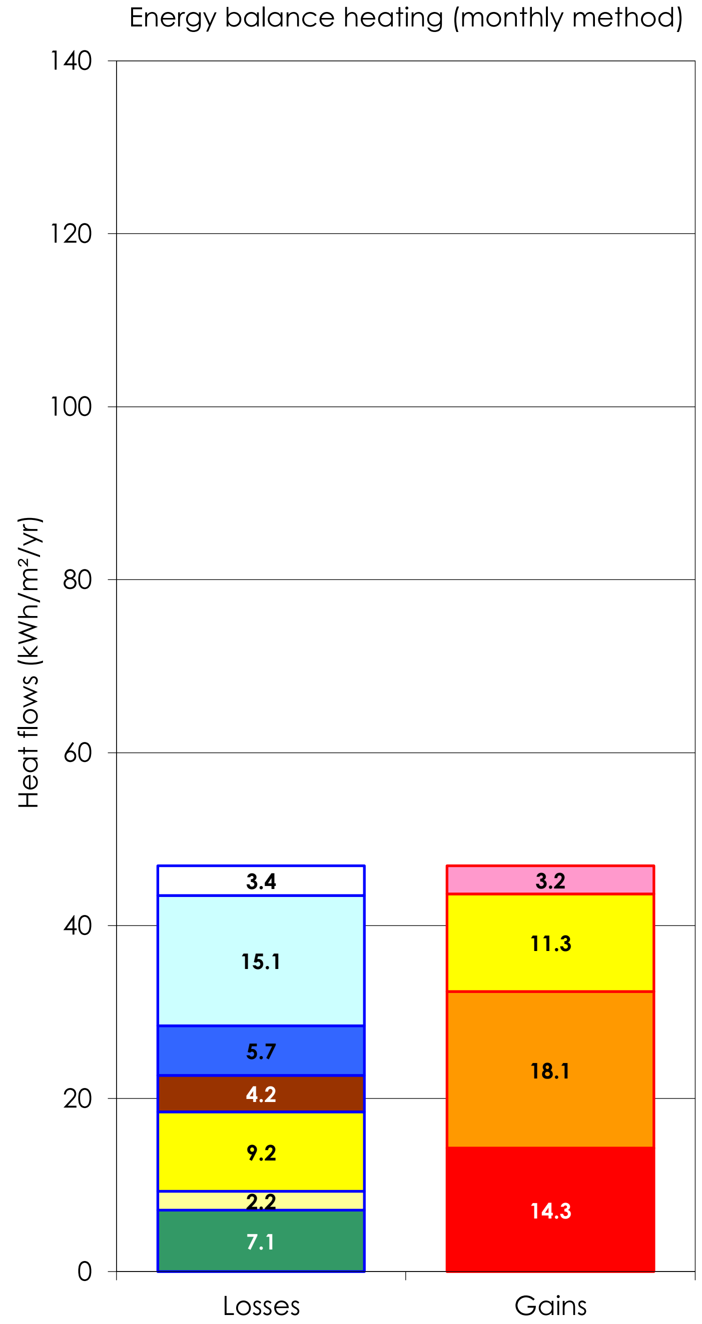
HT 421 - AECB CarbonLite

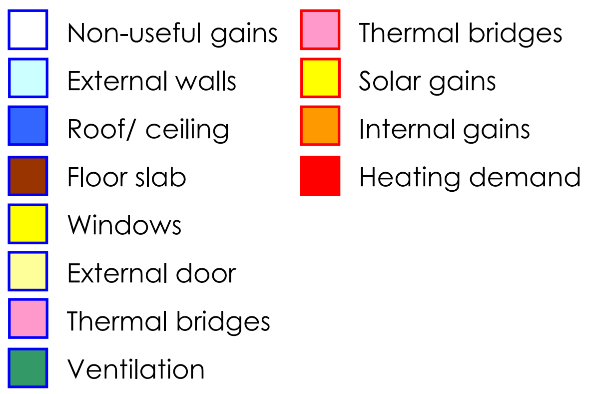


HT 421 - B&NES



HT 421 - LETI





This page contains the energy balance from PHPP for the four energy scenarios. These graphical outputs illustrate where both heat losses and gains - which must be balanced to maintain a stable, comfortable internal temperature - occur: this information can be used to interrogate the performance of the building fabric and optimise specifications.

Annual energy bills calculated by multiplying EUI by Ofgem Q2 2024 electricity unit rate of £0.245 per kWh

Projected Annual Electricity Bills

- AD:L (Wales) 2025 £1,274.00
- AECB CarbonLite £892.78
- B&NES £852.11
- LETI £815.36

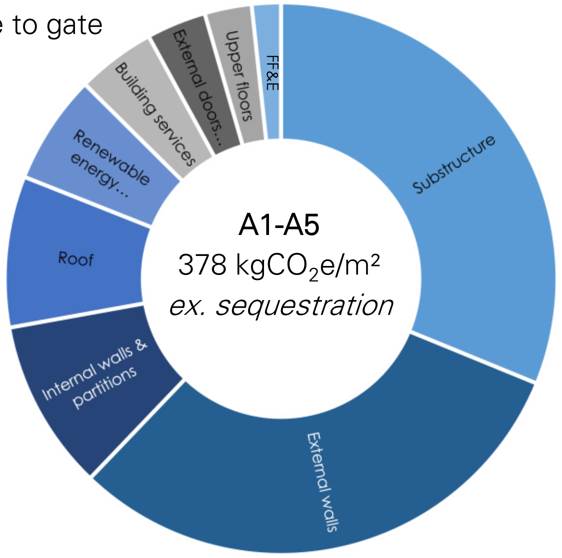
excludes standing charge & PV offsets

spring design

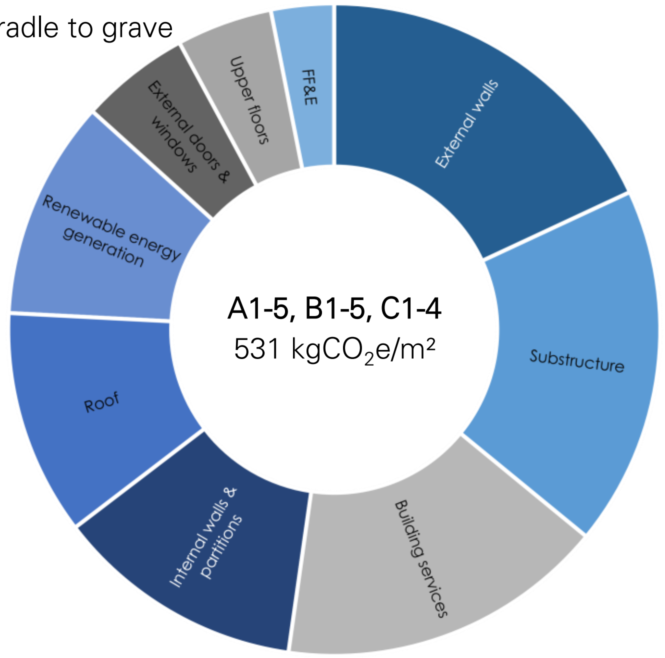
Embodied Scenarios

HT 421 - Scenario 1
BUA: Masonry with PIR
diagrams exclude groundworks

Cradle to gate



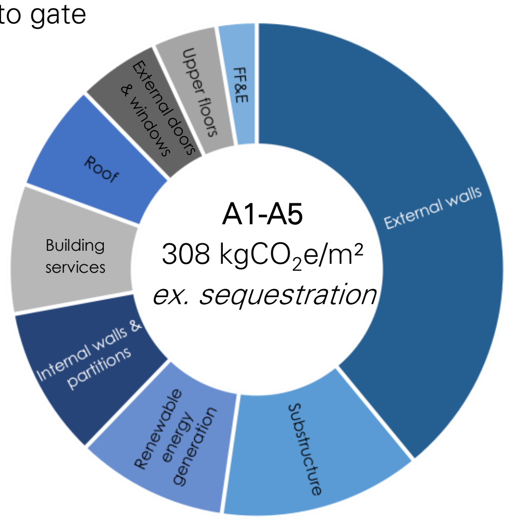
Cradle to grave



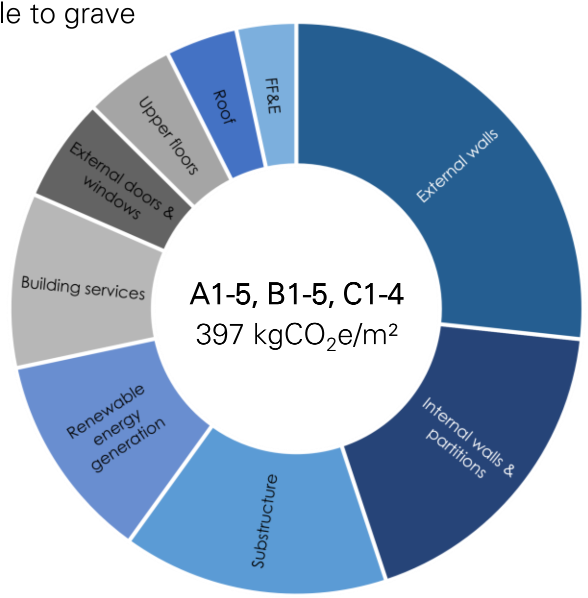
Sequestered
99 $kgCO_2e/m^2$

HT 421 - Scenario 2
Framed: 140mm Stud Mineral Wool & PIR
diagrams exclude groundworks

Cradle to gate



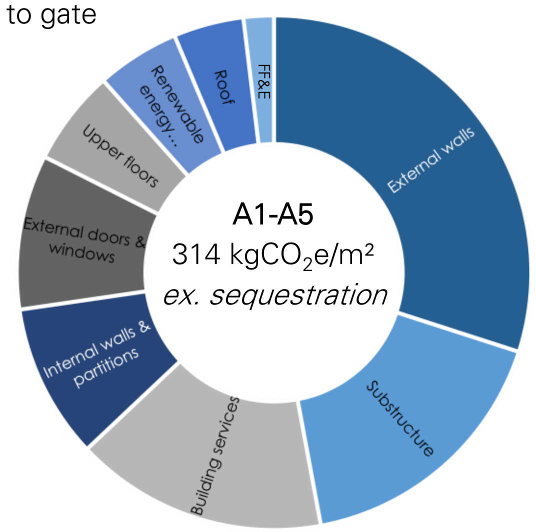
Cradle to grave



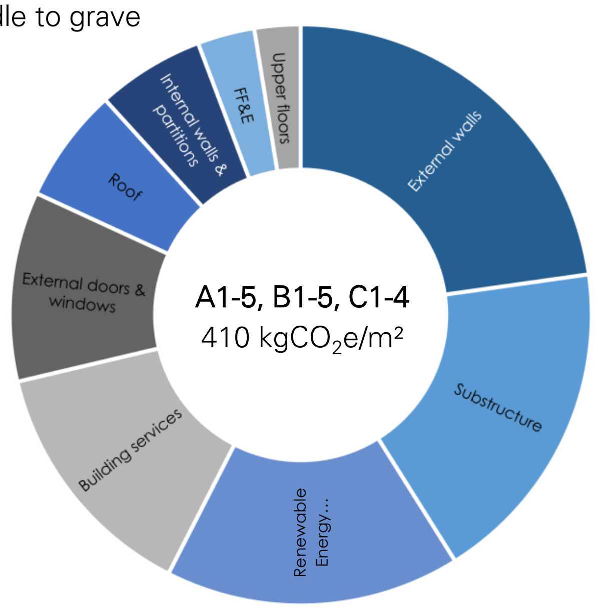
Sequestered
184 $kgCO_2e/m^2$

HT 421 - Scenario 3
Timber: 140mm Stud Woodfibre
diagrams exclude groundworks

Cradle to gate



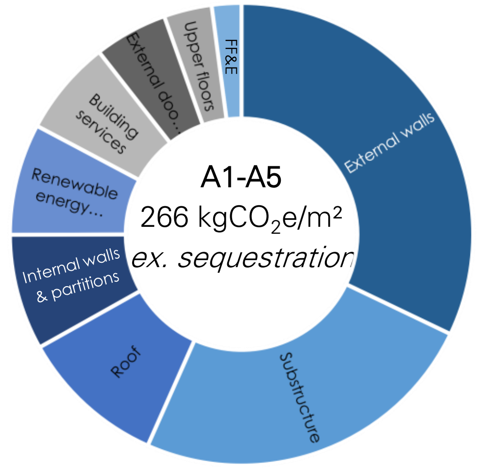
Cradle to grave



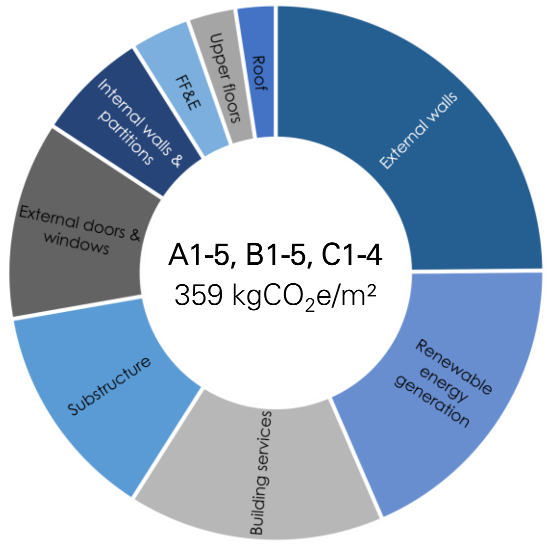
Sequestered
286 $kgCO_2e/m^2$

HT 421 - Scenario 4
Timber Optimised: Twin Stud Cellulose
diagrams exclude groundworks

Cradle to gate



Cradle to grave



Sequestered
267 $kgCO_2e/m^2$

5.2.3 HT 641

This section contains the quantitative assessment of **HT 641**. For illustrative drawings of the building and its modelled context, please refer to 7: Appendices.

Operational outputs demonstrate the potential to reduce space heating demand more than 80% by improving from AD: L (Wales) 2025 to LETI operational scenarios. This results in a 30% reduction in EUI, potential CO_2e emissions and the number of photovoltaics required to achieve Net Zero.

This typology does not manage to achieve the targeted EUI of 40 kWh/m²/yr. Representing the least efficient of the modelled typologies, it was considered most appropriate to allow this to fail rather than adjust or customise the residential specification to pass.

Installing panels on both roof slopes accommodates a maximum 32 panels. Assuming 400W panels this translates into a potential 12.8 kWp array. While there is headroom between maximum renewable capacity and the photovoltaics required to balance AD: L (Wales) 2025, an optimised South-facing dwelling could not host the full array on the South roof slope.

As with the preceding typologies the roof cannot vary substantially: the pitch cannot be flattened or the gables hipped without reducing the potential number of panels; additional dormers or rooflights would also reduce the size of the array. Reduction of heating demand should be the priority to allow flexibility in the design of the roof and facilitate the potential for an additional storey if densification is required.

Embodied outputs and the colour-coded LETI diagram demonstrate the relative carbon intensities of the modelled construction scenarios. Excluding internal finishes and fittings, all timber scenarios achieve RIBA/RIAI 2030 targets but all fail to meet LETI 2030 upfront emission target of 300 $kgCO_2e/m^2$.

Operational outputs - HT 641

Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	CO_2e emissions ex. PV (60 yrs)	kWp of PV to Net Zero per dwelling
1 AD: L (Wales) 2025	79.5 kWh/m²/yr	65.6 kWh/m²/yr	7,242 kWh	27.20 tonnes	10.0 kWp
2 AECB CarbonLite	35.8 kWh/m²/yr	48.4 kWh/m²/yr	5,343 kWh	20.10 tonnes	7.4 kWp
3 B&NES	27.3 kWh/m²/yr	46.3 kWh/m²/yr	5,112 kWh	19.20 tonnes	7.0 kWp
4 LETI	15.1 kWh/m²/yr	44.5 kWh/m²/yr	4,913 kWh	18.50 tonnes	6.8 kWp

Embodied outputs - HT 641

Option	RIBA/ RIAI (cradle to grave)	LETI			
		Upfront carbon A1-5	Embodied carbon A1-5, B1-5, C1-4	Sequestered carbon	Module D (offsite benefits)
1 Masonry	748 $kgCO_2e/m^2$	422 $kgCO_2e/m^2$	589 $kgCO_2e/m^2$	107 $kgCO_2e/m^2$	-72 $kgCO_2e/m^2$
2 Framed	580 $kgCO_2e/m^2$	327 $kgCO_2e/m^2$	420 $kgCO_2e/m^2$	185 $kgCO_2e/m^2$	-104 $kgCO_2e/m^2$
3 Timber	593 $kgCO_2e/m^2$	326 $kgCO_2e/m^2$	433 $kgCO_2e/m^2$	293 $kgCO_2e/m^2$	-175 $kgCO_2e/m^2$
4 Timber Optimised	560 $kgCO_2e/m^2$	305 $kgCO_2e/m^2$	400 $kgCO_2e/m^2$	303 $kgCO_2e/m^2$	-135 $kgCO_2e/m^2$

Headlines for HT 641

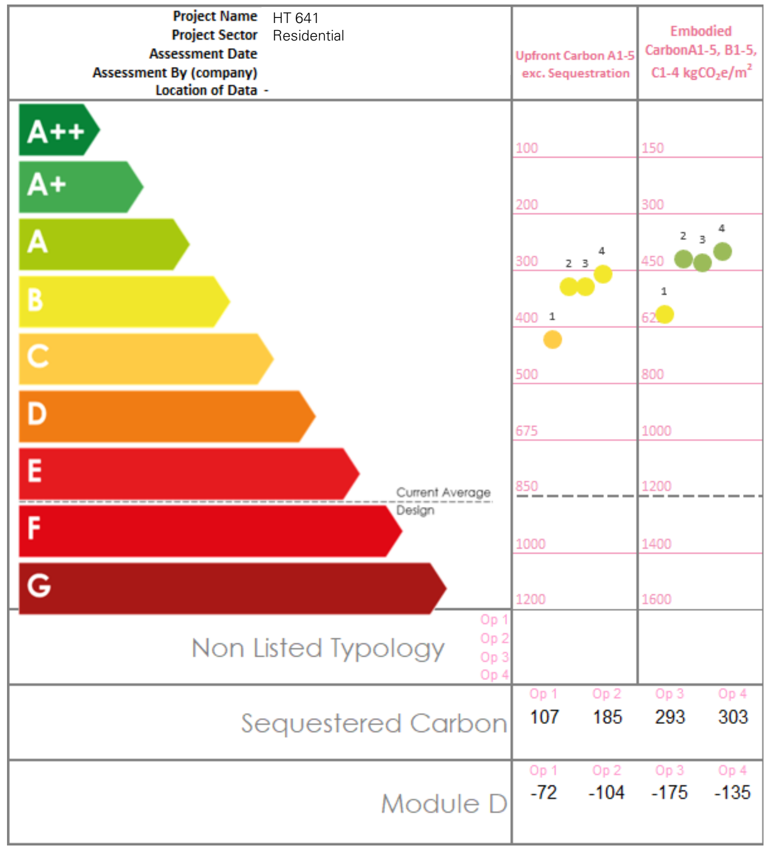
- EUI & CO_2e reductions of 30% in upgrading **AD: L (Wales) 2025** to **LETI**
- PV provisions for **AD: L (Wales) 2025** cannot fit on a single roof slope
- Timber reduces embodied carbon by 30% vs. masonry with PIR & cellulose insulation sequesters 2.8x more CO_2e
- Timber with cellulose insulation has sequestered carbon just under the upfront embodied emissions

Twin Stud Cellulose (Scenario 4) delivers the lowest carbon intensity, prioritising short-term rotation and recycled biogenic materials, reducing upfront carbon 6% more than other timber options and 30% more than masonry with 2.8x more carbon sequestered. For this typology the sequestered carbon of Twin Stud Cellulose almost equals upfront carbon emissions.

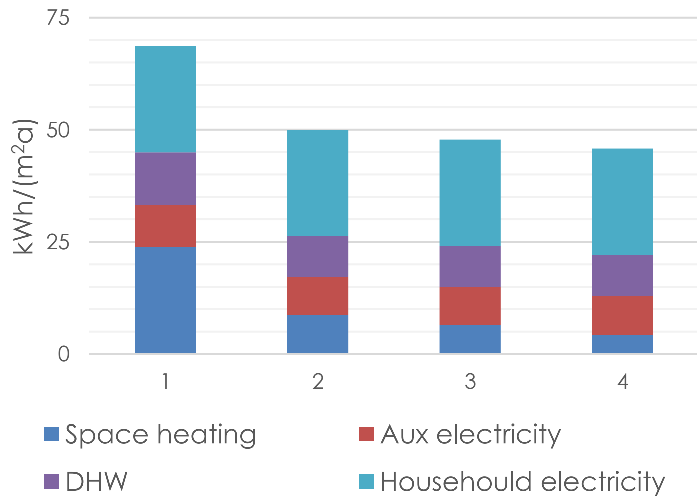
Detailed embodied information is diagrammed on page 25. Acknowledging future production processes are not modelled as decarbonised as would be correct in RICS WLCA 2nd edition, it is worth noting the relative emissions associated with maintaining a 6.8 kWp array for the 60 year reference period.

Energy consumption by use opposite shows how use is split between heating, domestic hot water, auxiliary electricity and household electricity. The modelled variables only impact energy associated with heating.

LETI embodied carbon reporting - HT 641

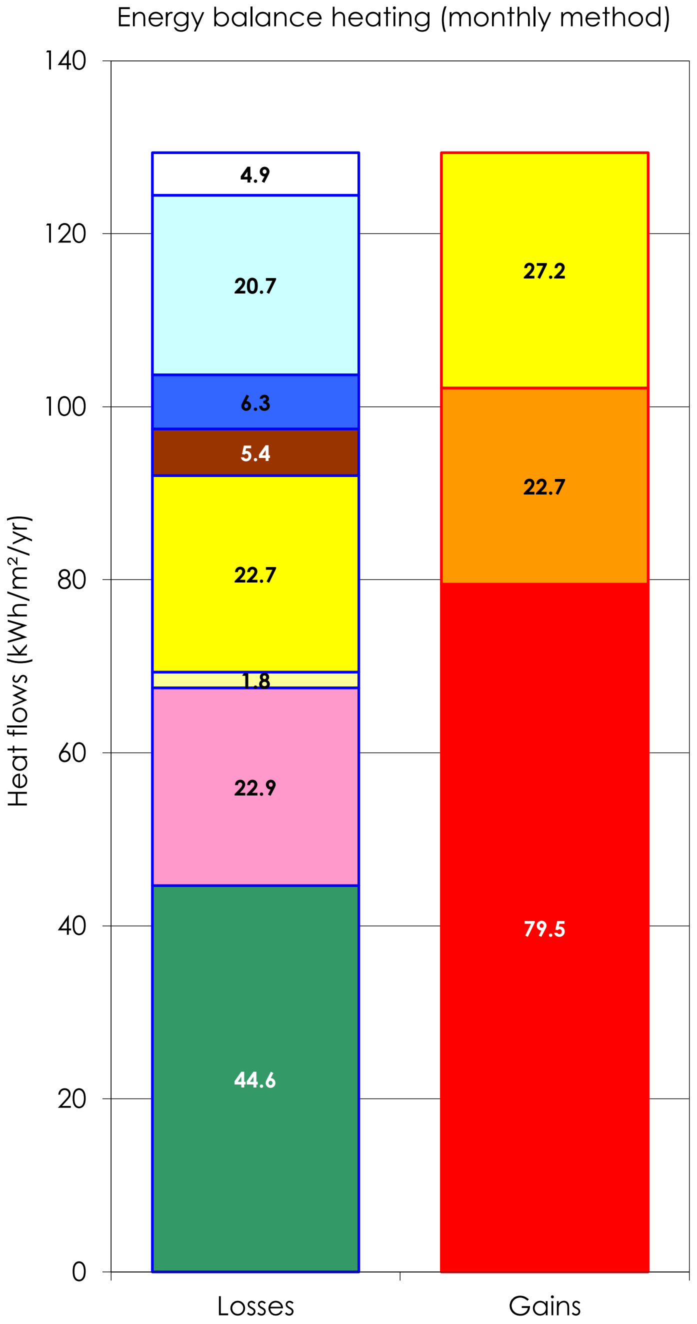


Energy consumption by use - HT 641

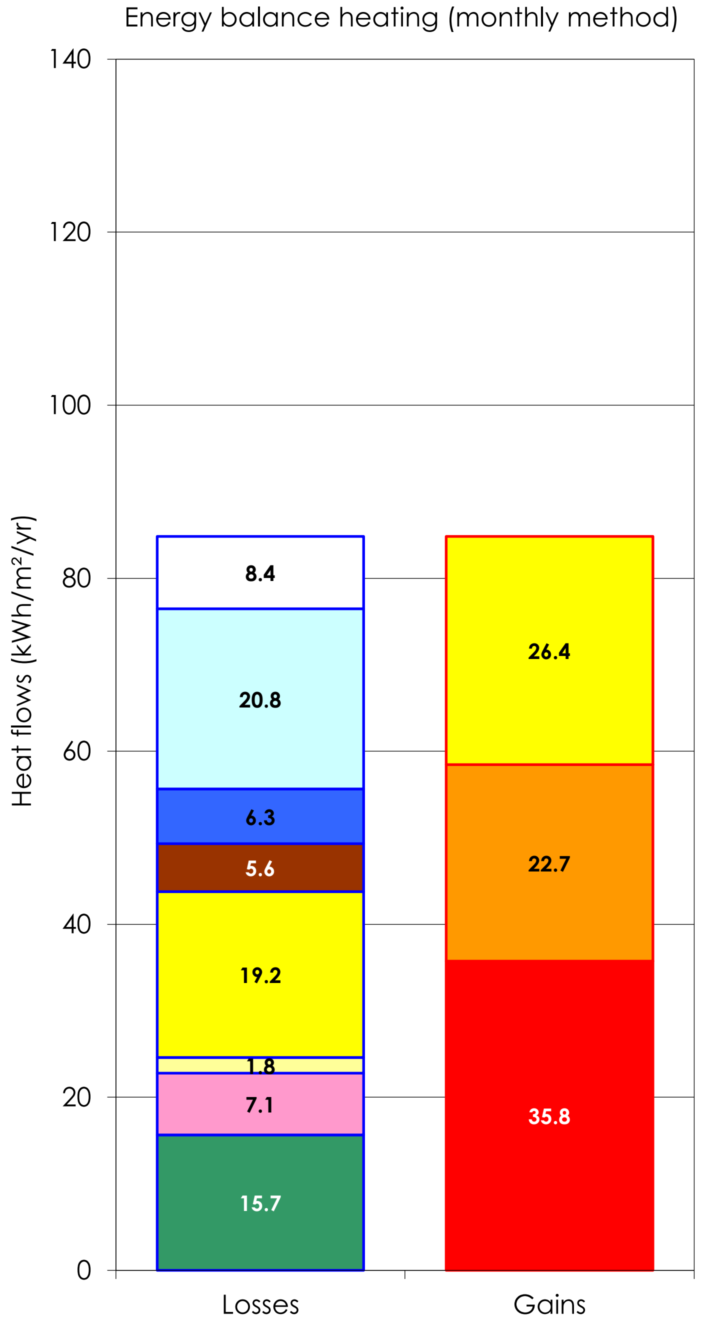


Operational Scenarios

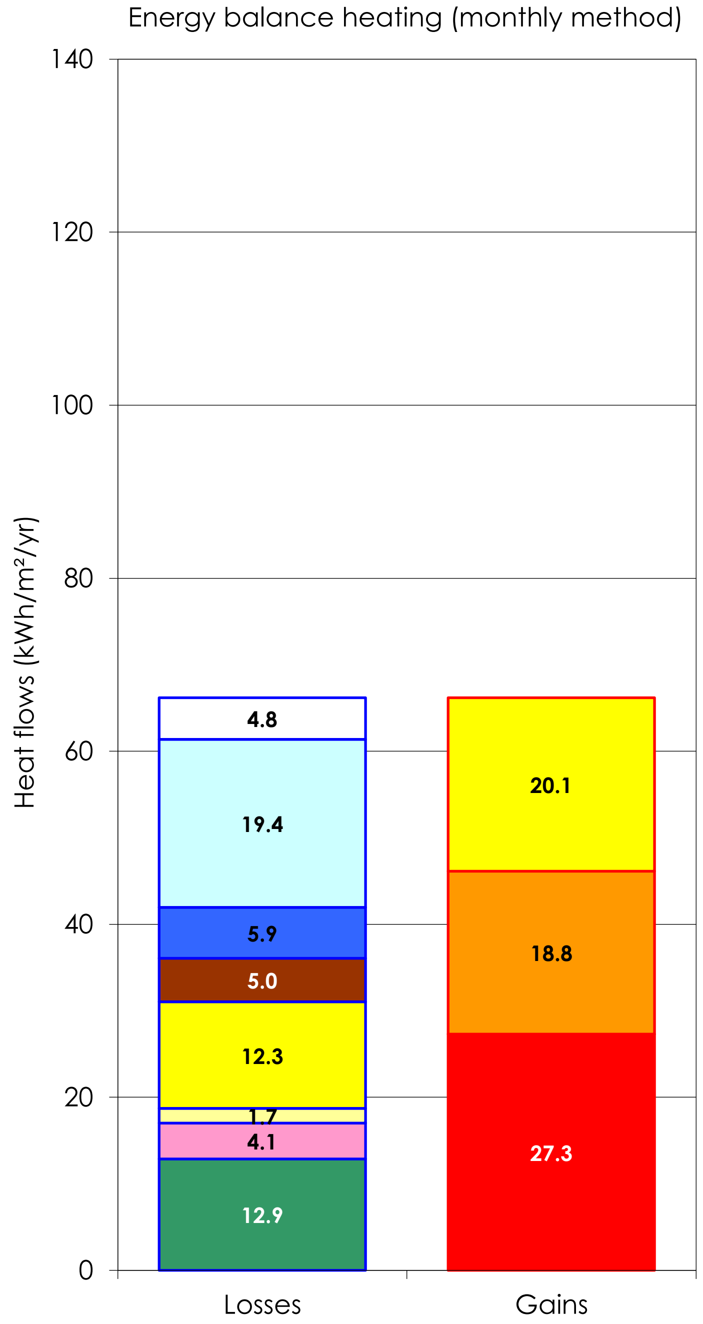
HT 641 - AD: L (Wales) 2025



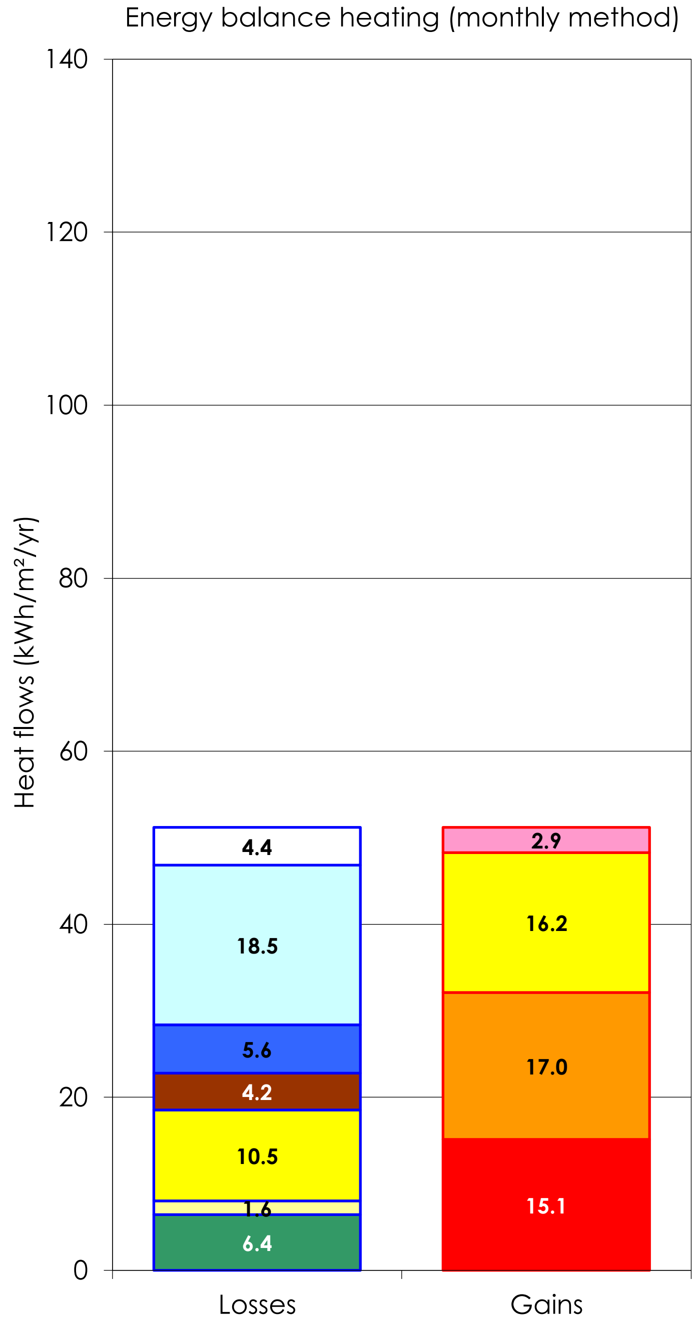
HT 641 - AECB CarbonLite



HT 641 - B&NES



HT 641 - LETI



- Non-useful gains
- External walls
- Roof/ ceiling
- Floor slab
- Windows
- External door
- Thermal bridges
- Ventilation
- Thermal bridges
- Solar gains
- Internal gains
- Heating demand

This page contains the energy balance from PHPP for the four energy scenarios. These graphical outputs illustrate where both heat losses and gains - which must be balanced to maintain a stable, comfortable internal temperature - occur: this information can be used to interrogate the performance of the building fabric and optimise specifications.

Annual energy bills calculated by multiplying EUI by Ofgem Q2 2024 electricity unit rate of £0.245 per kWh

Projected Annual Electricity Bills

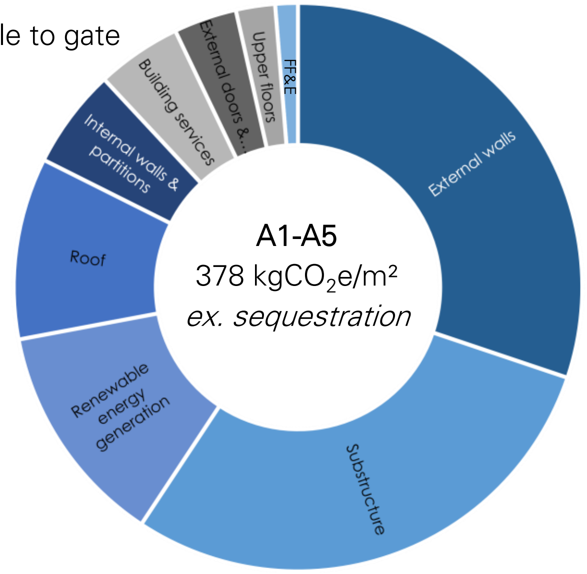
• AD:L (Wales) 2025	£1,774.29
• AECB CarbonLite	£1,309.04
• B&NES	£1,252.44
• LETI	£1,203.69

excludes standing charge & PV offsets

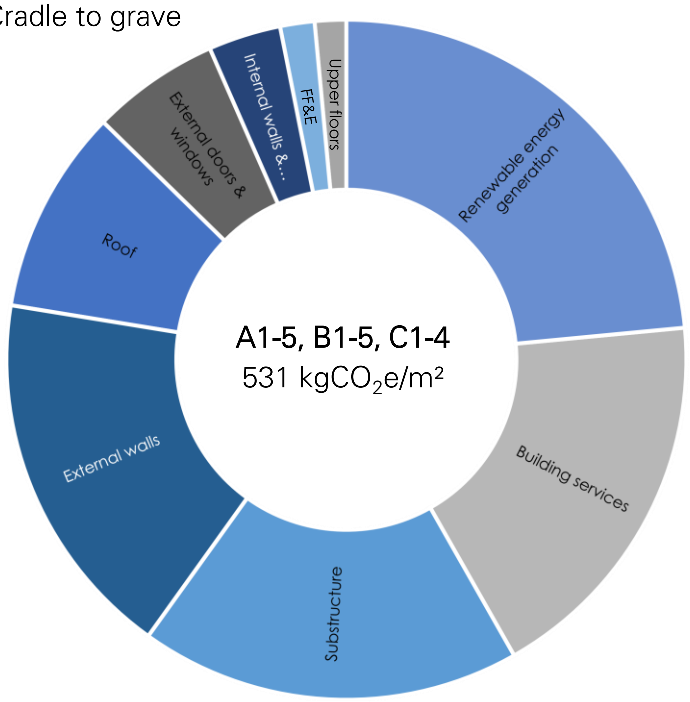
Embodied Scenarios

HT 641 - Scenario 1
Masonry: Masonry with PIR
diagrams exclude groundworks

Cradle to gate

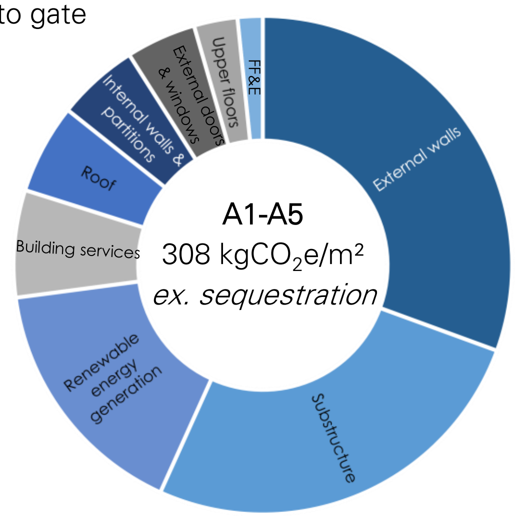


Cradle to grave

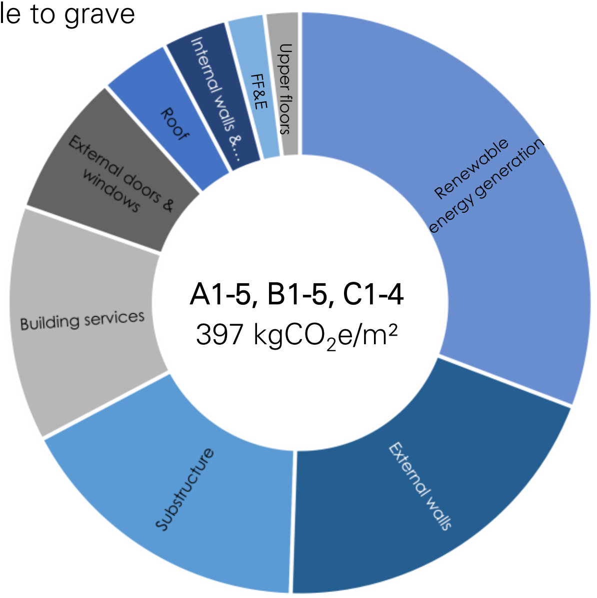


HT 641 - Scenario 2
Framed: 140mm Stud Mineral Wool & PIR
diagrams exclude groundworks

Cradle to gate

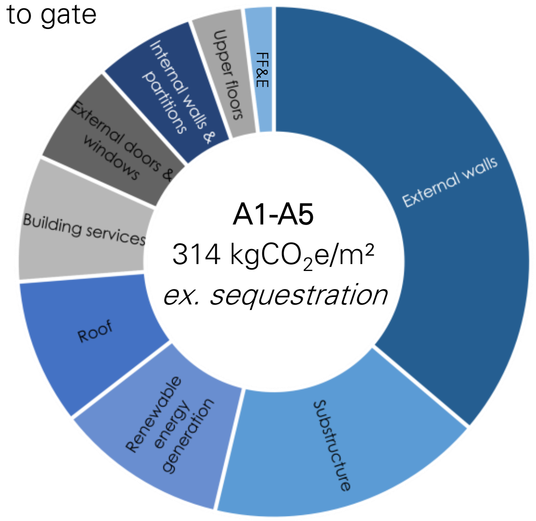


Cradle to grave

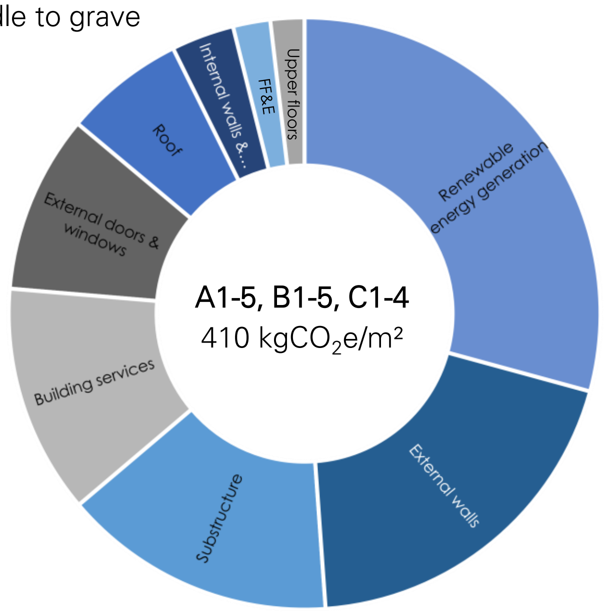


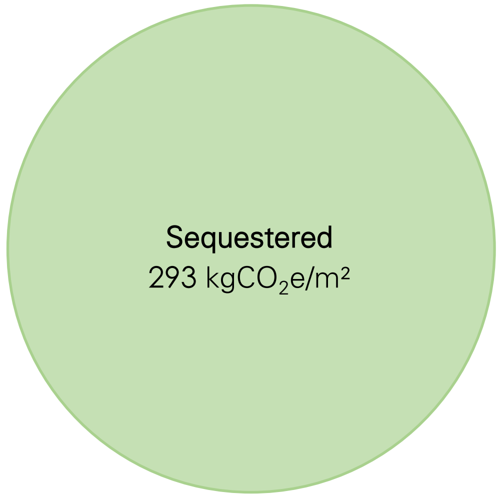
HT 641 - Scenario 3
Timber: 140mm Stud Woodfibre
diagrams exclude groundworks

Cradle to gate



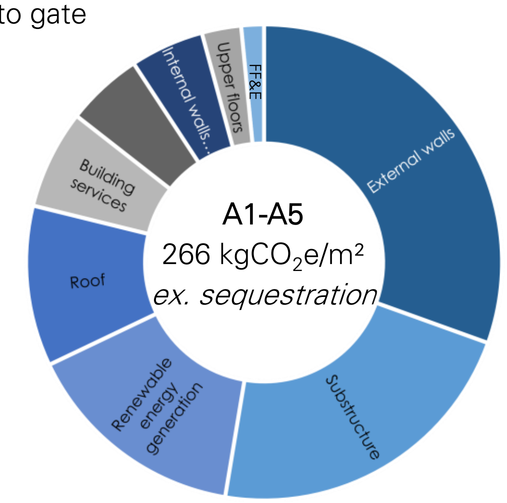
Cradle to grave



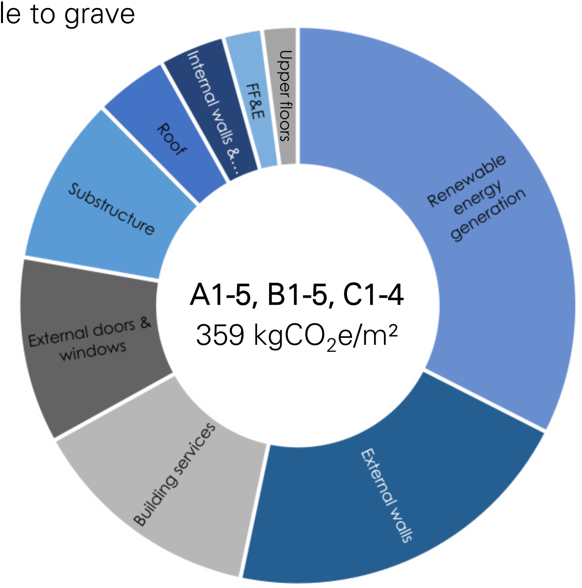


HT 641 - Scenario 4
Timber Optimised: Twin Stud Cellulose
diagrams exclude groundworks

Cradle to gate



Cradle to grave



5.3 Non-Residential

5.3.1 OF 315

This section contains the quantitative assessment of **OF 315**. For illustrative drawings of the building and its modelled context, please refer to 7: Appendices.

Operational outputs demonstrate the potential to reduce space heating demand 85% by improving from AD: L (Wales) 2025 to LETI operational scenarios. This results in a 30% reduction in EUI, potential CO_2e emissions and the number of photovoltaics required to achieve Net Zero.

The form of this typology could be much more energy efficient than the current configuration. If the form were optimised the fabric specification could reduce (as **SC 1492**) and still achieve the highest performance targets: reducing the depth (and therefore overall quantity) of insulation applied to the building would lower the associated embodied carbon emissions.

Current roof designs can accommodate 76 panels on the East slope and 30 on the West slope for a maximum 106 panels: assuming 400W panels this translates into a potential 42.4 kWp array. While there is significant headroom between maximum capacity and the requirements of AD: L (Wales) 2025 to reach Net Zero the capital cost and embodied energy of an increased array must not be underestimated.

Embodied outputs and the colour-coded LETI diagram demonstrate the relative carbon intensities of the modelled construction scenarios, exhibiting a much wider range of results than the residential typologies. Excluding internal finishes and fittings, only Twin Stud Cellulose (Scenario 4) achieves either the targets for RIBA/ RIAI 2030 (offices) or LETI 2030 (non-domestic) upfront emissions.

Twin Stud Cellulose delivers the lowest carbon intensity, prioritising short-term rotation and recycled biogenic materials, and reduces upfront carbon 25% beyond the other timber scenario and 45% more than masonry with 10x more carbon sequestered. In this application its sequestered carbon significantly exceeds upfront carbon emissions.

Detailed embodied information is diagrammed on page 28. Acknowledging future production processes are not decarbonised as RICS WLCA 2nd edition, it is worth noting the relative emissions maintaining a 21.6 kWp array for the 60 year reference period are the largest contributors of CO_2e for both timber scenarios.

Energy consumption by use opposite shows how use is split between heating, hot water, auxiliary electricity and user electricity. Conservatively calculated, the majority of energy consumed is clearly attributed to user electricity regardless of operational scenario. This could be addressed by improving the efficiency of the electrical appliances within the office.

Operational outputs - OF 315

Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use	CO_2e emissions ex. PV (60 yrs)	kWp of PV to achieve Net Zero
1 AD: L (Wales) 2025	70.1 kWh/m²/yr	71.1 kWh/m²/yr	22,375 kWh	84.20 tonnes	28.8 kWp
2 AECB CarbonLite	33.3 kWh/m²/yr	66.5 kWh/m²/yr	20,928 kWh	78.80 tonnes	26.8 kWp
3 B&NES	21.4 kWh/m²/yr	57.8 kWh/m²/yr	18,190 kWh	68.40 tonnes	23.2 kWp
4 LETI	10.6 kWh/m²/yr	51.1 kWh/m²/yr	16,081 kWh	60.60 tonnes	21.6 kWp

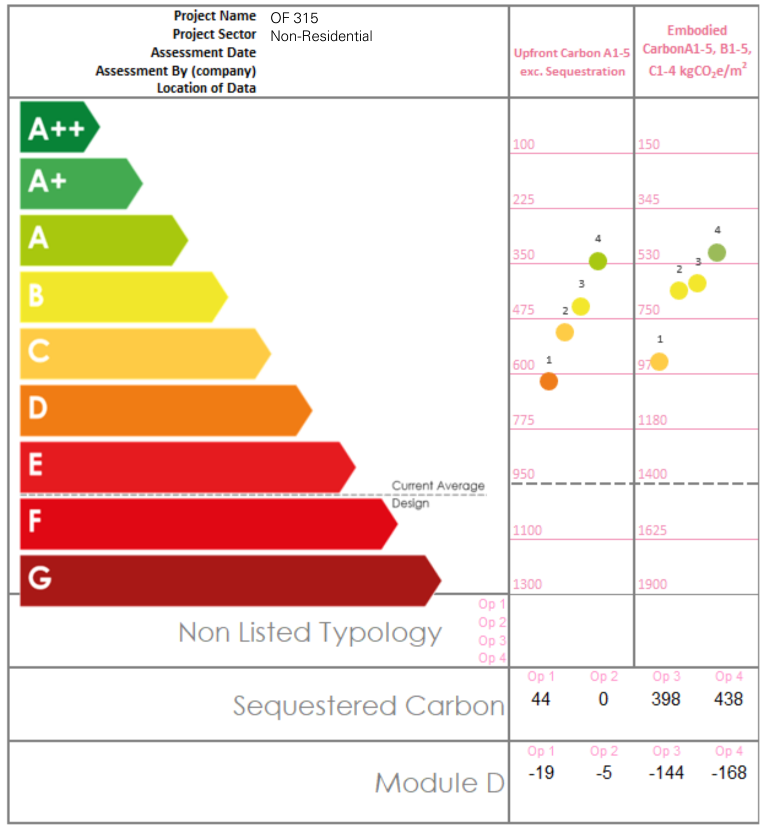
Embodied outputs - OF 315

Option	RIBA/ RIAI (cradle to grave)	LETI			
		Upfront carbon A1-5	Embodied carbon A1-5, B1-5, C1-4	Sequestered carbon	Module D (offsite benefits)
1 Masonry	1149 $kgCO_2e/m^2$	624 $kgCO_2e/m^2$	925 $kgCO_2e/m^2$	44 $kgCO_2e/m^2$	-31 $kgCO_2e/m^2$
2 Framed	824 $kgCO_2e/m^2$	507 $kgCO_2e/m^2$	646 $kgCO_2e/m^2$	0 $kgCO_2e/m^2$	-17 $kgCO_2e/m^2$
3 Timber	1032 $kgCO_2e/m^2$	447 $kgCO_2e/m^2$	617 $kgCO_2e/m^2$	398 $kgCO_2e/m^2$	-156 $kgCO_2e/m^2$
4 Timber Optimised	669 $kgCO_2e/m^2$	344 $kgCO_2e/m^2$	497 $kgCO_2e/m^2$	438 $kgCO_2e/m^2$	-168 $kgCO_2e/m^2$

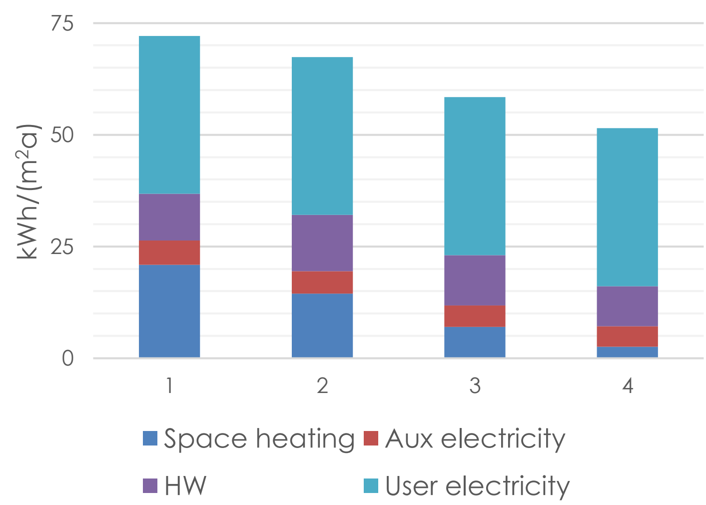
Headlines for OF 315

- EUI & CO_2e reductions of 30% in upgrading **AD: L (Wales) 2025** to **LETI**
- User electricity largest contributor to energy consumption of typology
- Timber reduces embodied carbon by 30% vs. masonry with PIR & cellulose insulation sequesters 10x more CO_2e
- Timber with cellulose insulation sequesters more CO_2e than the upfront emissions from construction

LETI embodied carbon reporting - OF 315

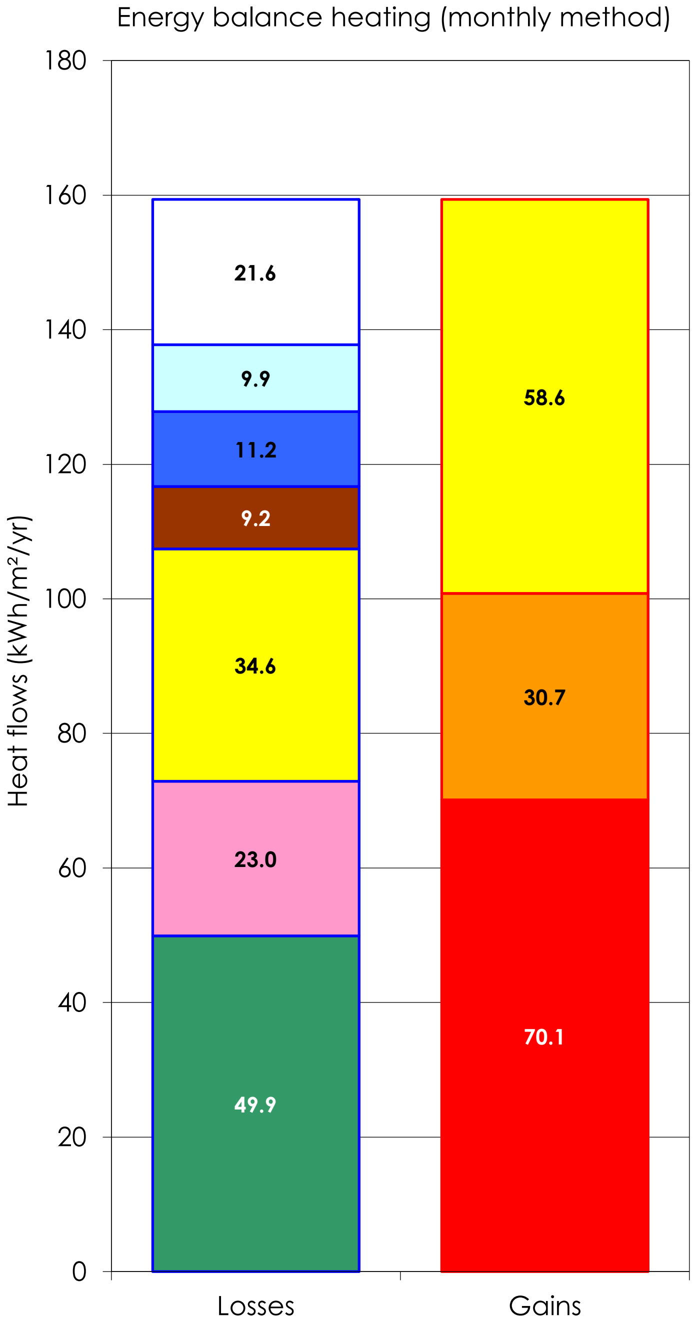


Energy consumption by use - OF 315

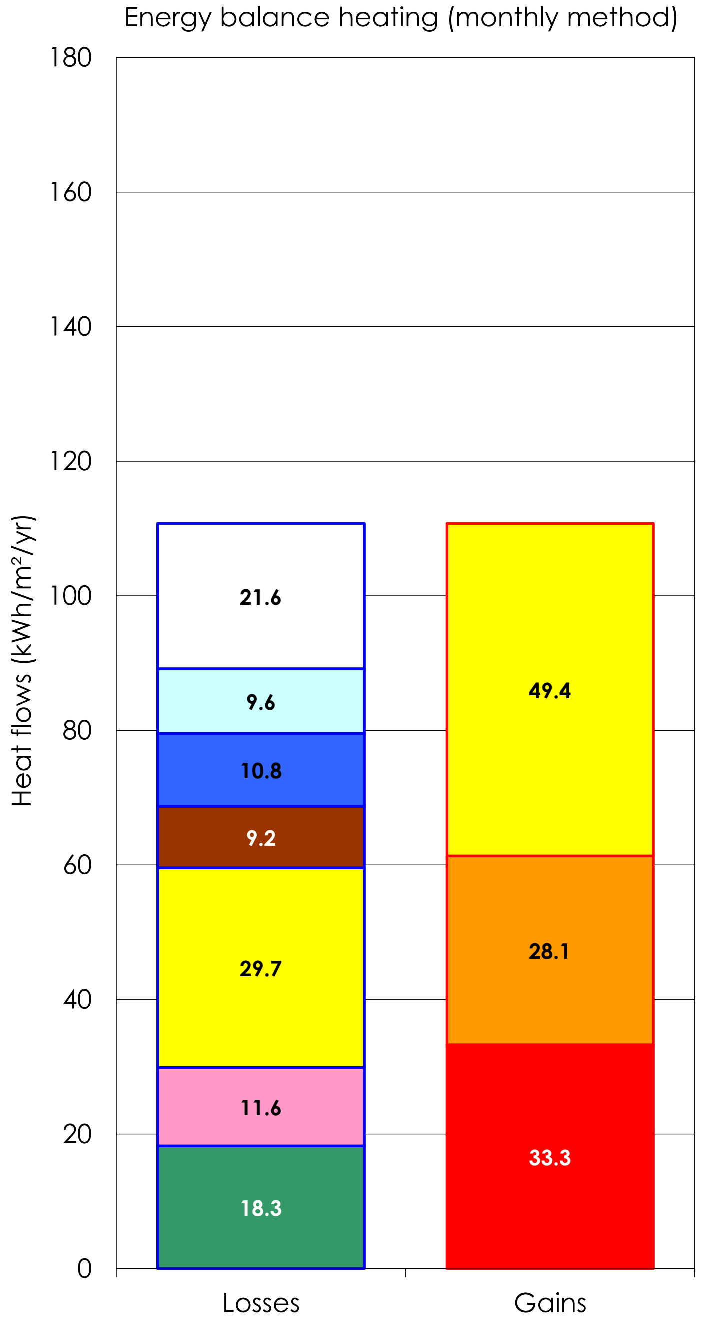


Operational Scenarios

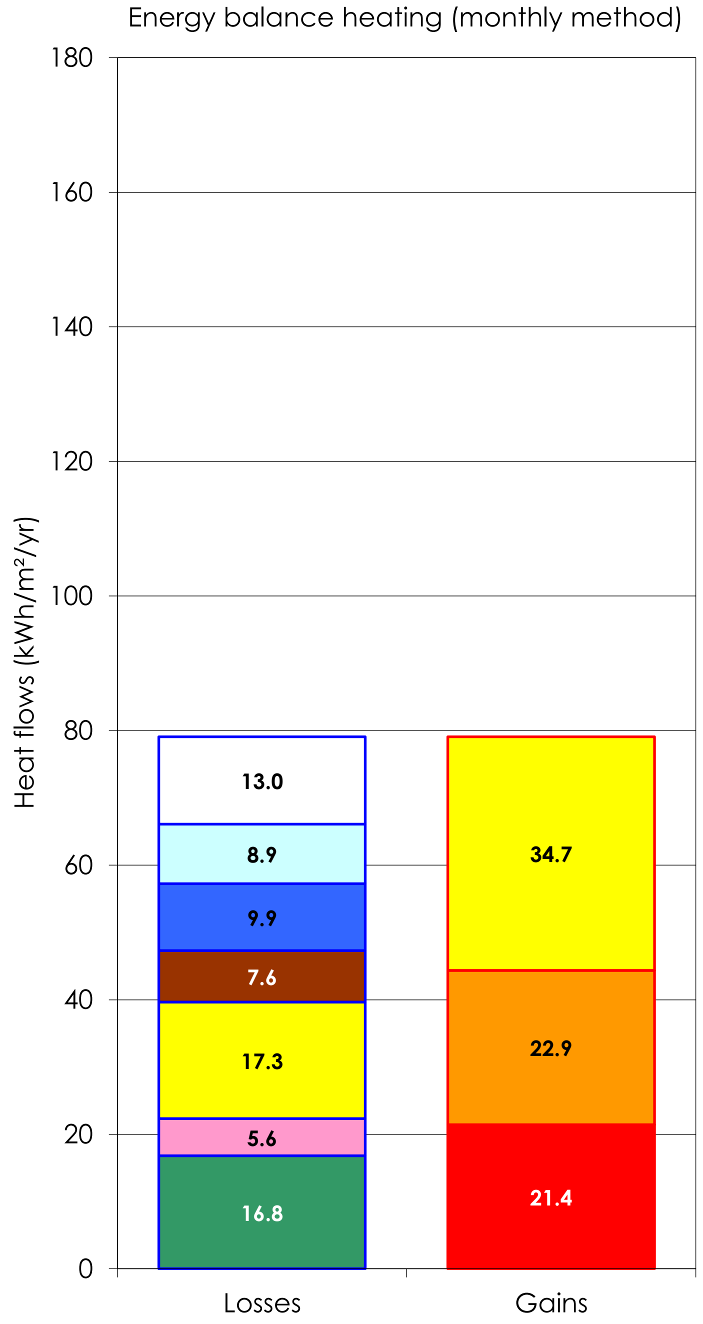
OF 315 - AD: L (Wales) 2025



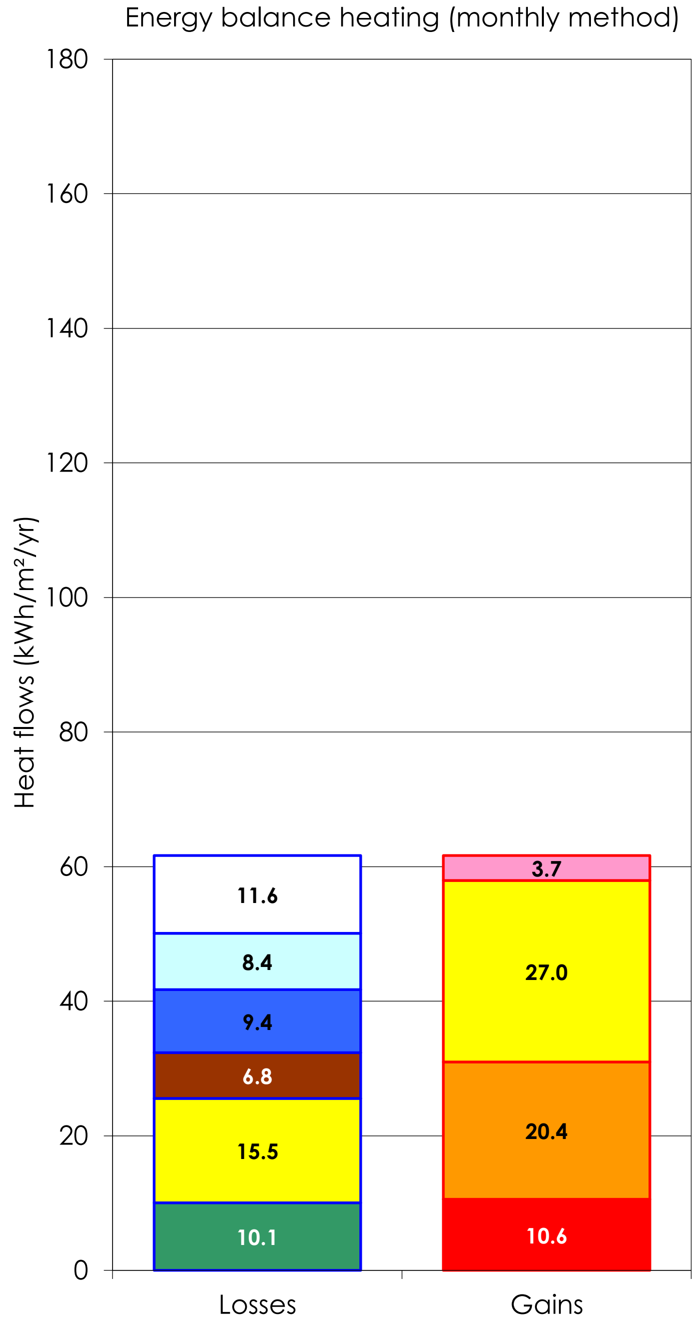
OF 315 - AECB CarbonLite



OF 315 - B&NES



OF 315 - LETI



- Non-useful gains
- External walls
- Roof/ ceiling
- Floor slab
- Windows
- External door
- Thermal bridges
- Ventilation
- Thermal bridges
- Solar gains
- Internal gains
- Heating demand

This page contains the energy balance from PHPP for the four energy scenarios. These graphical outputs illustrate where both heat losses and gains - which must be balanced to maintain a stable, comfortable internal temperature - occur: this information can be used to interrogate the performance of the building fabric and optimise specifications.

Annual energy bills calculated by multiplying EUI by Ofgem Q2 2024 electricity unit rate of £0.252 per kWh

Projected Annual Electricity Bills

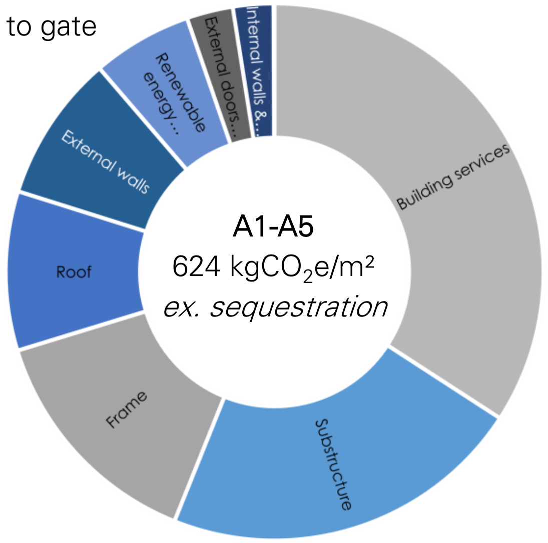
- AD:L (Wales) 2025 £5,638.50
- AECB CarbonLite £5,273.86
- B&NES £4,583.88
- LETI £4,052.41

excludes standing charge & PV offsets

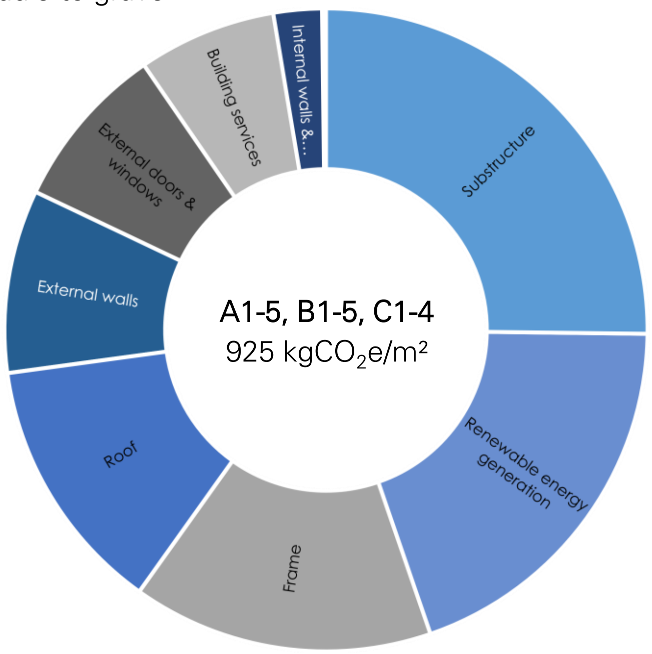
Embodied Scenarios

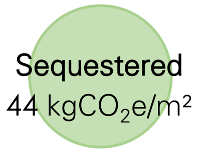
OF 315 - Scenario 1
Masonry: Masonry with PIR
diagrams exclude groundworks

Cradle to gate



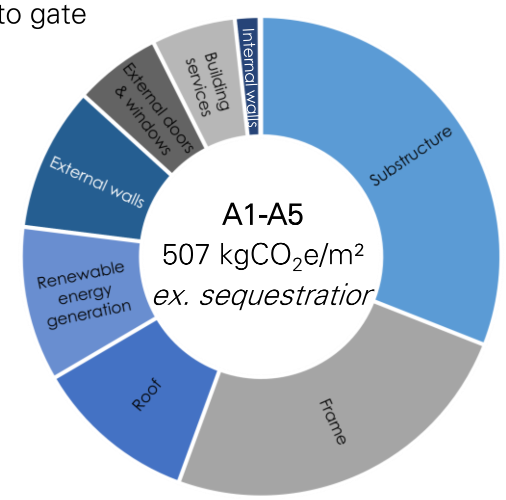
Cradle to grave



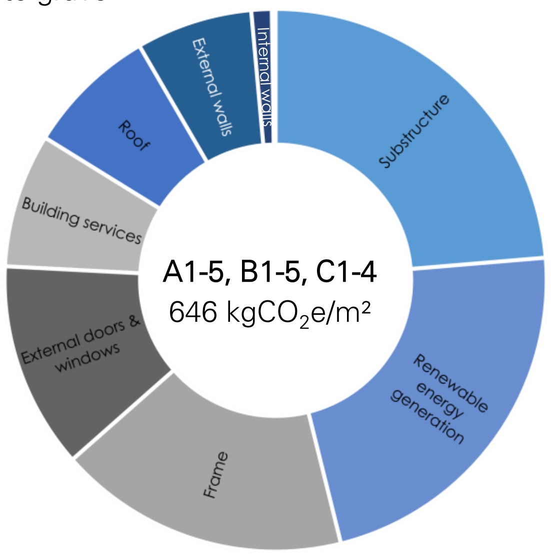


OF 315 - Scenario 2
Framed: Steel Frame with PIR Panels
diagrams exclude groundworks

Cradle to gate



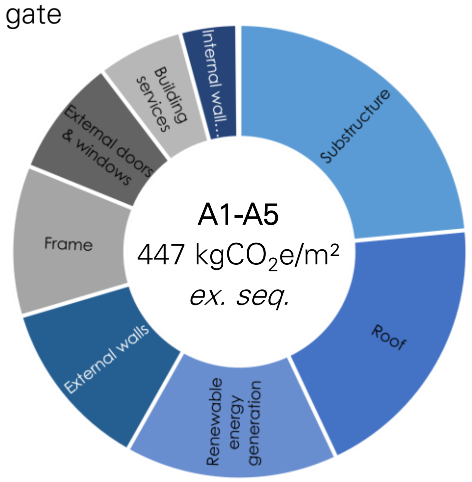
Cradle to grave



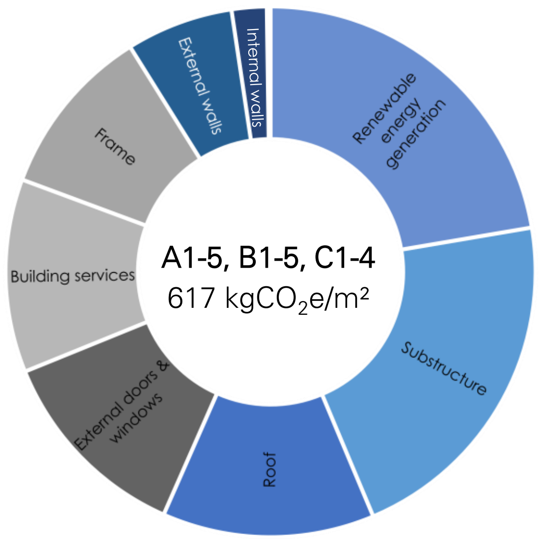
Sequestered
0 kgCO$_2$e/m²

OF 315 - Scenario 3
Timber: Timber Stud Woodfibre
diagrams exclude groundworks

Cradle to gate

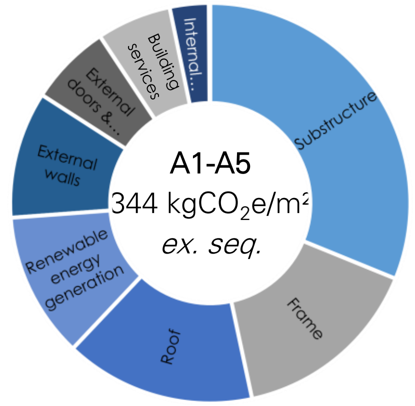


Cradle to grave

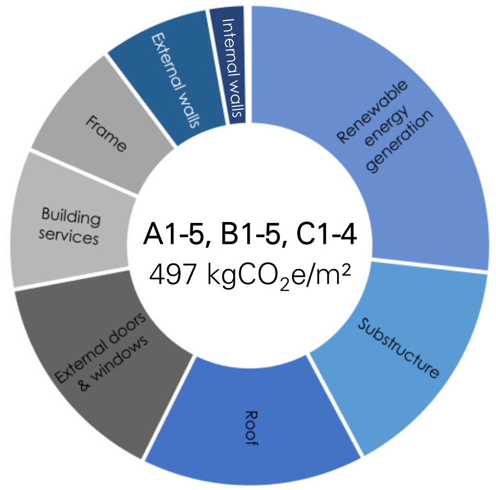


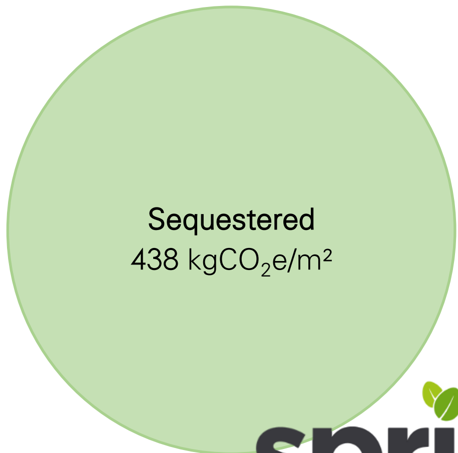
OF 315 - Scenario 4
Timber Optimised: Twin Stud Cellulose
diagrams exclude groundworks

Cradle to gate



Cradle to grave





spring design

5.3.2 SC 1492

This section contains the quantitative assessment of **SC 1492**. For illustrative drawings of the building and its modelled context, please refer to 7: Appendices.

Operational outputs demonstrate the potential to reduce space heating demand 75% by improving from AD: L (Wales) 2022 to LETI operational scenarios. This results in a 30% reduction in EUI, potential CO_2e emissions and the number of photovoltaics required to achieve Net Zero (which reduces material intensity).

At over 1500m² GIA this typology illustrates the benefits of good form factor. Despite the specification of the external envelope being significantly lower than **OF 315**, **SC 1492** still achieves LETI performance standards thanks to the low ratio of external surface (heat loss) area to internal volume. Reducing the depth and therefore overall quantity of insulation significantly lowers the associated embodied carbon emissions.

Current roof designs accommodate approximately 174 panels on the East and 87 on the West slope for a maximum 261 panels: assuming 400W panels this translates into a potential 104.4 kWp array. This fails to meet the required generational capacity to achieve Net Zero for either AECB CarbonLite or AD: L (Wales) 2022 with 2% and 25% deficits respectively.

Embodied outputs and the colour-coded LETI diagram demonstrate the relative carbon intensities of the modelled construction scenarios, exhibiting a wide range of results. Excluding internal finishes and fittings, only Twin Stud Cellulose (Scenario 4) achieves the RIBA/ RIAI 2030 (schools) or LETI 2030 (non-domestic) upfront emissions.

Twin Stud Cellulose achieves the lowest carbon intensity by prioritising short-term rotation crops and recycled biogenic materials. This materiality reduces upfront carbon 25% beyond the other timber scenario, 40% more than steel frame and 45% more than masonry. This same scenario sequesters more carbon within the building than the upfront emissions generated by the construction of the building.

Operational outputs - SC 1492					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use	CO_2e emissions ex. PV (60 yrs)	kWp of PV to achieve Net Zero
1 AD: L (Wales) 2022	56.7 kWh/m²/yr	73.6 kWh/m²/yr	109,811 kWh	345.0 tonnes	141.6 kWp
2 AECB CarbonLite	30.0 kWh/m²/yr	55.3 kWh/m²/yr	82,508 kWh	259.3 tonnes	106.4 kWp
3 B&NES	23.1 kWh/m²/yr	53.7 kWh/m²/yr	80,120 kWh	251.9 tonnes	103.6 kWp
4 LETI	15.1 kWh/m²/yr	52.7 kWh/m²/yr	78,628 kWh	246.8 tonnes	101.6 kWp

Embodied outputs - SC 1492					
		LETI			
Option	RIBA/ RIAI (cradle to grave)	Upfront carbon A1-5	Embodied carbon A1-5, B1-5, C1-4	Sequestered carbon	Module D (offsite benefits)
1 Masonry	703 $kgCO_2e/m^2$	412 $kgCO_2e/m^2$	536 $kgCO_2e/m^2$	35 $kgCO_2e/m^2$	-17 $kgCO_2e/m^2$
2 Framed	654 $kgCO_2e/m^2$	370 $kgCO_2e/m^2$	487 $kgCO_2e/m^2$	0 $kgCO_2e/m^2$	-4 $kgCO_2e/m^2$
3 Timber	631 $kgCO_2e/m^2$	308 $kgCO_2e/m^2$	464 $kgCO_2e/m^2$	294 $kgCO_2e/m^2$	-81 $kgCO_2e/m^2$
4 Timber Optimised	553 $kgCO_2e/m^2$	232 $kgCO_2e/m^2$	387 $kgCO_2e/m^2$	292 $kgCO_2e/m^2$	-71 $kgCO_2e/m^2$

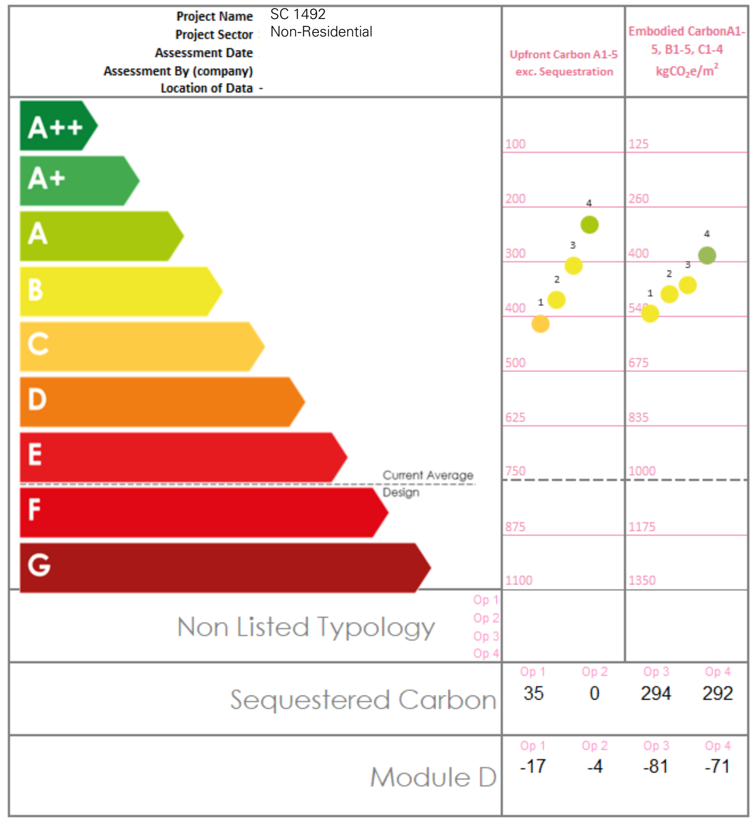
Headlines for SC 1492

- EUI & CO_2e reductions of 30% in upgrading **AD: L (Wales) 2022** to **LETI**
- Hot water usage largest contributor to energy consumption of typology
- Timber reduces embodied carbon by 30% vs. masonry with PIR & cellulose insulation sequesters 8x more CO_2e
- Timber with cellulose insulation sequesters more CO_2e than the upfront emissions from construction

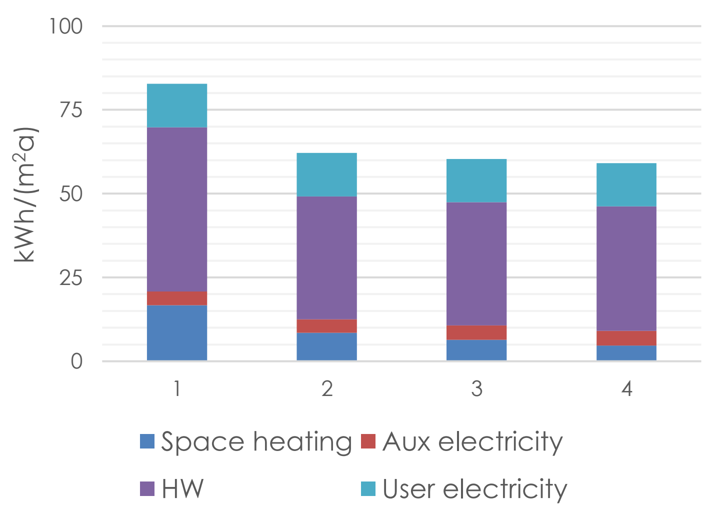
Detailed embodied information is diagrammed on page 31. Acknowledging future production processes are not decarbonised as RICS WLCA 2[nd] edition, it is worth noting the relative emissions maintaining a 101.6 kWp array for the 60 year reference period are the largest contributors of CO_2e for all embodied scenarios.

Energy consumption by use opposite shows how use is split between heating, hot water, auxiliary electricity and user electricity. Hot water consumption comprises the majority of energy use regardless of operational scenario. This is perhaps unsurprising within a densely populated educational setting: optimisations might include waste water heat recovery (WWHR).

LETI embodied carbon reporting - SC 1492

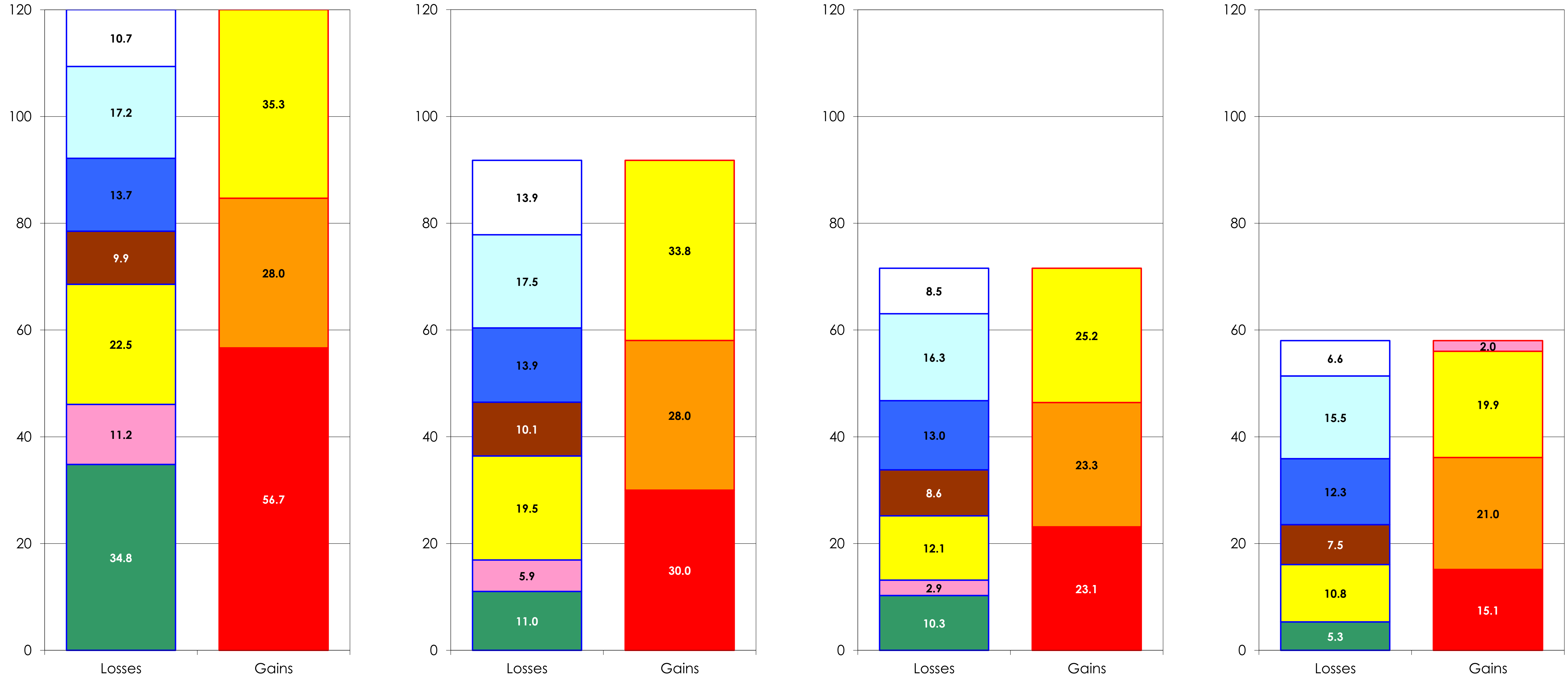


Energy consumption by use - SC 1492



Operational Scenarios

SC 1492 - AD: L (Wales) 2022 | SC 1492 - AECB CarbonLite | SC 1492 - B&NES | SC 1492 - LETI



- Non-useful gains
- External walls
- Roof/ ceiling
- Floor slab
- Windows
- External door
- Thermal bridges
- Ventilation
- Thermal bridges
- Solar gains
- Internal gains
- Heating demand

This page contains the energy balance from PHPP for the four energy scenarios. These graphical outputs illustrate where both heat losses and gains - which must be balanced to maintain a stable, comfortable internal temperature - occur: this information can be used to interrogate the performance of the building fabric and optimise specifications.

Annual energy bills calculated by multiplying EUI by Ofgem Q2 2024 electricity unit rate of £0.251 per kWh

Projected Annual Electricity Bills

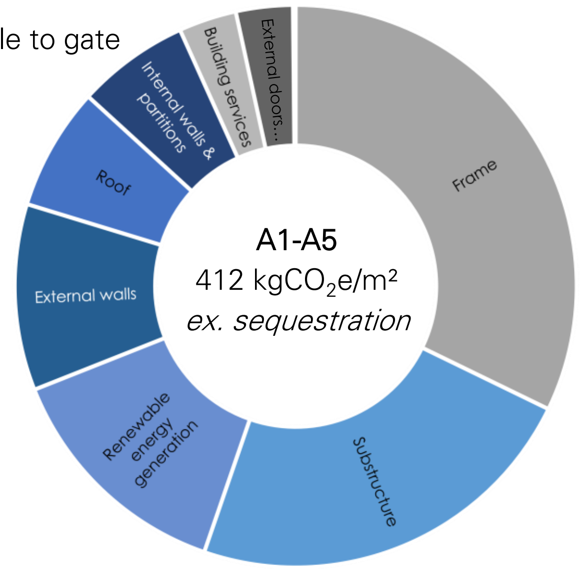
- AD:L (Wales) 2025 £27,562.56
- AECB CarbonLite £20,709.51
- B&NES £20,110.12
- LETI £19,735.63

excludes standing charge & PV offsets

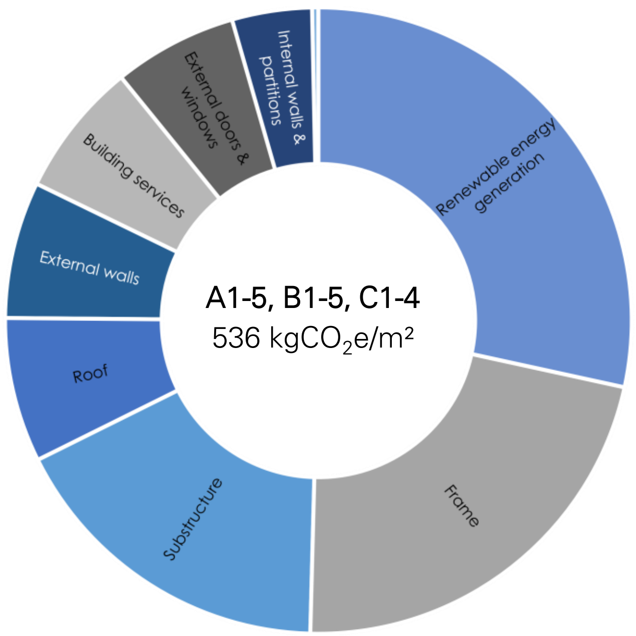
Embodied Scenarios

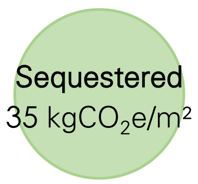
SC 1492 - Scenario 1
Masonry: Masonry with PIR
diagrams exclude groundworks

Cradle to gate



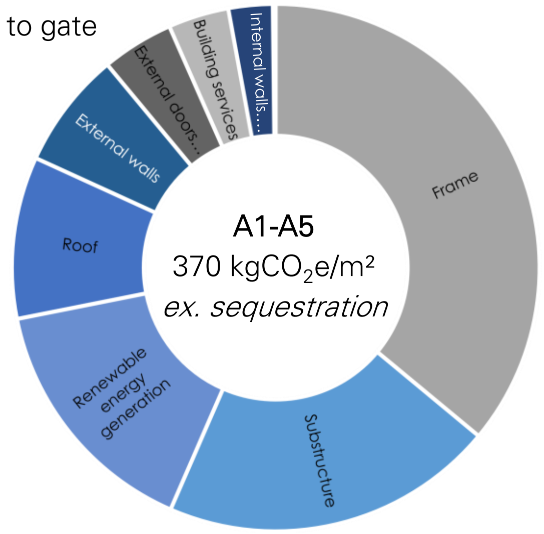
Cradle to grave



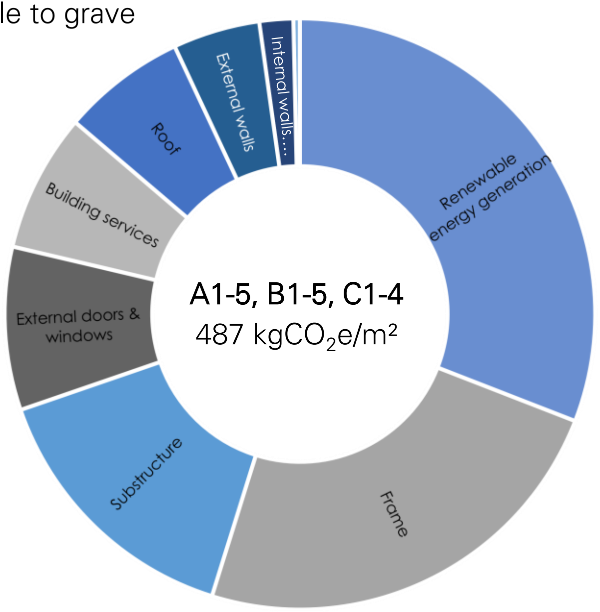


SC 1492 - Scenario 2
Framed: Steel Frame with PIR Panels
diagrams exclude groundworks

Cradle to gate



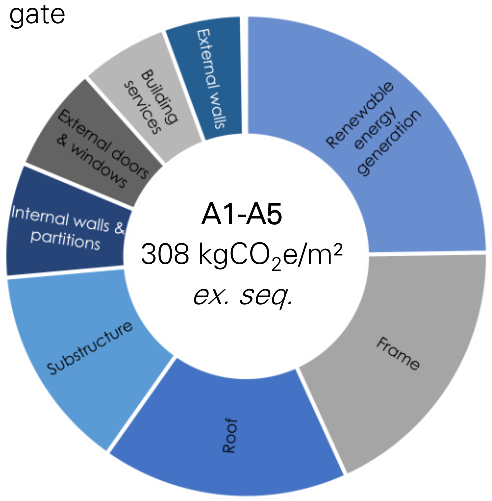
Cradle to grave



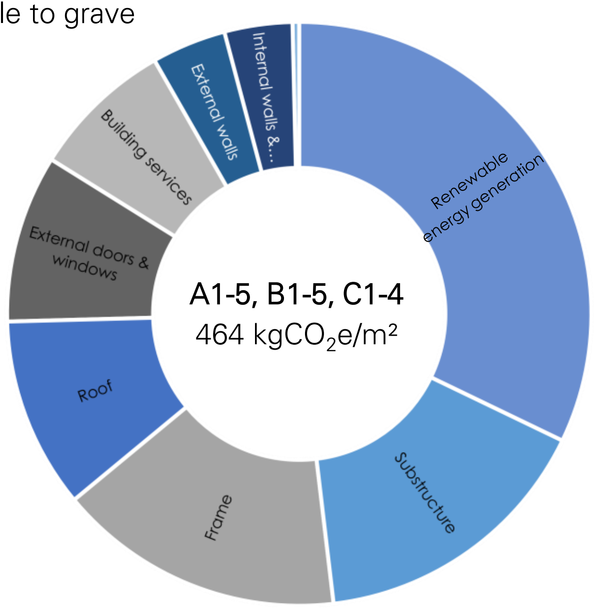
Sequestered
0 kgCO$_2$e/m²

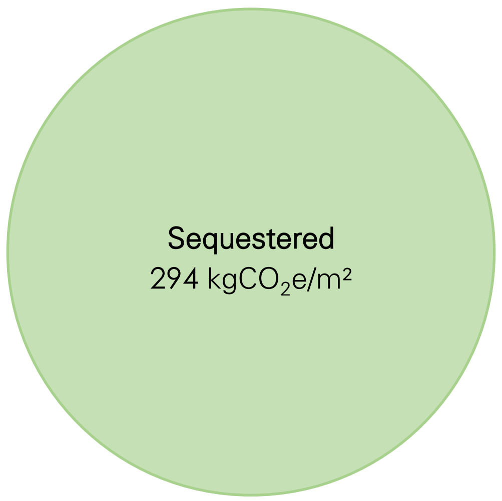
SC 1492 - Scenario 3
Timber: Timber Stud Woodfibre
diagrams exclude groundworks

Cradle to gate



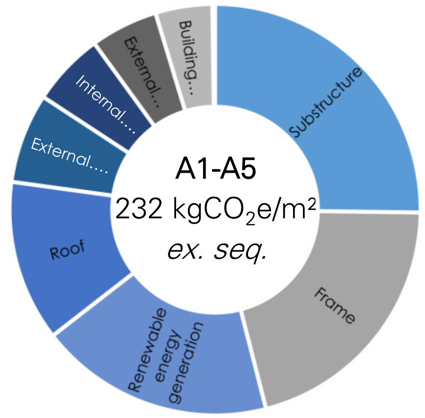
Cradle to grave



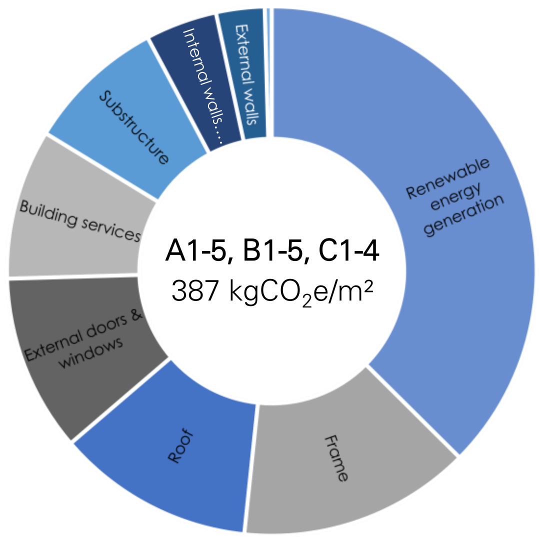


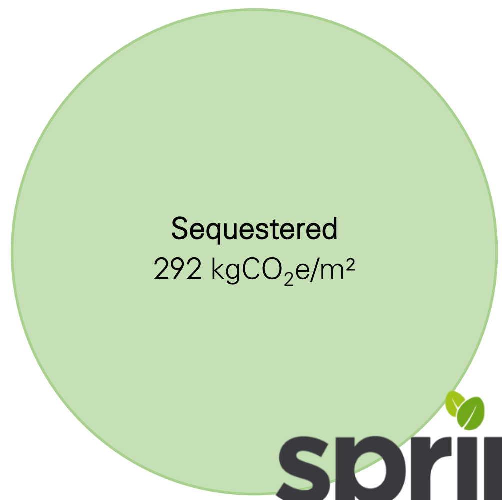
SC 1492 - Scenario 4
Timber Optimised: Twin Stud Cellulose
diagrams exclude groundworks

Cradle to gate



Cradle to grave





Section 6: Conclusions

6.1 Conclusions

As demonstrated through this quantitative assessment operational and embodied carbon emissions can be reduced by minor optimisations with no bearing on physical appearance. Without altering the layout or external materiality of the assessed typologies, operational emissions were reduced 30-40% and embodied emissions 20-30%.

High performance buildings are achievable without significantly altering the fabric specification of the anticipated 2025 Building Regulations. Uplifts beyond basic compliance are limited to improved airtightness, mitigation of thermal bridges, improved quality of windows and provision of MVHR for ventilation.

Improved levels of building performance result in an inherently lower need for heat generation and on-site renewables. This can reduce the number of photovoltaic panels required to achieve Net Zero and the size of heat pumps and heating infrastructure.

In the case of larger buildings, or those that are otherwise optimised, targeting heating demand or EUI based performance metrics could leverage potential reductions in insulation thicknesses with the resulting material efficiencies benefitting embodied emissions.

Choice of construction methodology can significantly impact embodied emissions. The principle of replacing mineral and petrochemical-based materials with short-rotation biogenic alternatives lowers embodied emissions while increasing sequestration potential.

This assessment has focused on a range of residential and non-residential typologies modelled on a nominal site at 50m altitude. Applying typical design responses in an East-West orientation to achieve the identified operational performance standards demonstrates the technical feasibility of Net Zero. Further operational optimisations - including but not limited to improved form factor, orientation and fenestration design - could achieve operational Net Zero more efficiently and drive a reduction in embodied emissions.

Headlines for operational analysis

- Heating demand reductions > 80% achievable between identical buildings by improving airtightness & thermal bridging complemented by MVHR
- EUI & CO_2e reductions of 30-40% available applying these improvements
- Reduced EUI requires 30-40% fewer PV panels to achieve Net Zero balance
- Heat pumps reduce energy required for heating & hot water demand to < 25% of the direct electric equivalent

Headlines for embodied analysis

- Higher-density building typologies can facilitate material efficiencies that result in lower embodied carbon
- Changing from masonry construction to timber frame reduces CO_2e 20-30%
- Timber frame with biogenic insulants can sequester 3-5x CO_2e as equivalent built in masonry with PIR insulation
- Improved form factor can achieve high performance standards with less insulation, saving embodied carbon

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Section 7: Appendices

7.1 Building Typologies

7.1.1 Residential

Refer to drawings:

2740-211(02)100 - HT 211 Notional Site Layout
2740-211(02)101 - HT 211 Notional Street Elevation
2740-211(02)200 - HT 211 GF Plan
2740-211(02)201 - HT 211 1F Plan
2740-211(02)202 - HT 211 2F Plan
2740-211(02)300 - HT 211 Elevations
2740-211(02)301 - HT 211 Elevations

2740-421(02)100 - HT 421 Notional Site Layout
2740-421(02)200 - HT 421 Floor Plans
2740-421(02)300 - HT 421 Elevations

2740-621(02)100 - HT 641 Notional Site Layout
2740-621(02)200 - HT 641 Floor Plans
2740-621(02)300 - HT 641 Elevations

7.1.2 Non-Residential

Refer to drawings:

2740-315(02)100 - OF 315 Notional Site Layout
2740-315(02)101 - OF 315 Notional Street Elevation
2740-315(02)200 - OF 315 GF Plan
2740-315(02)300 - OF 315 Elevations

2740-1492(02)100 - SC 1492 Notional Site Layout
2740-1492(02)200 - SC 1492 Floor Plans
2740-1492(02)300 - SC 1492 Elevations

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Unit 2
Chapel Barns
Merthyr Mawr
Bridgend
CF32 0LS

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W: www.spring-consultancy.co.uk

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Civil Engineering
Structural Engineering
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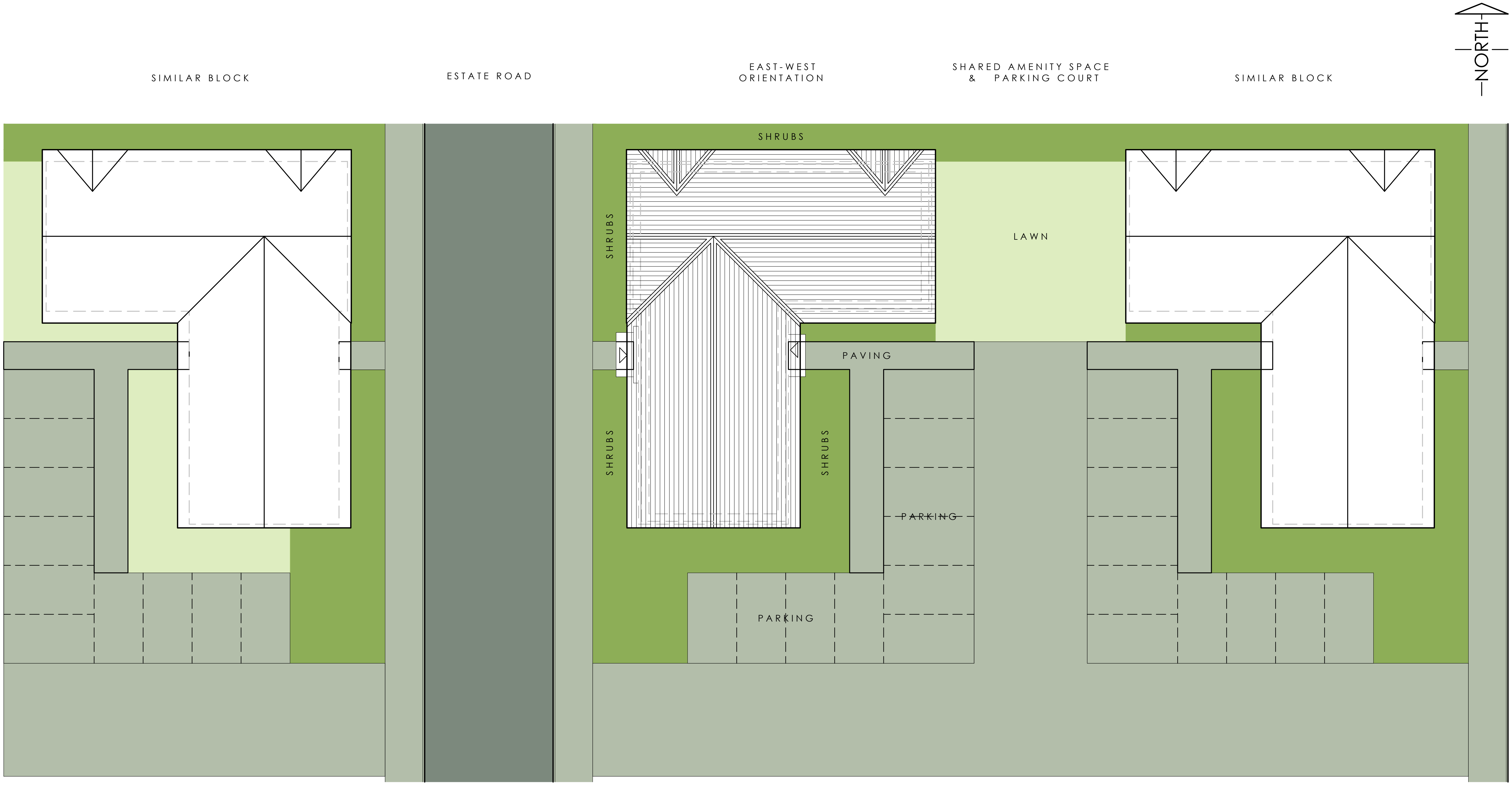

NOTIONAL SITE LAYOUT

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 211 CA Notional Site Layout

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	08.01.24	JD		JM	1:200 @ A3	2740	211(02)100	-

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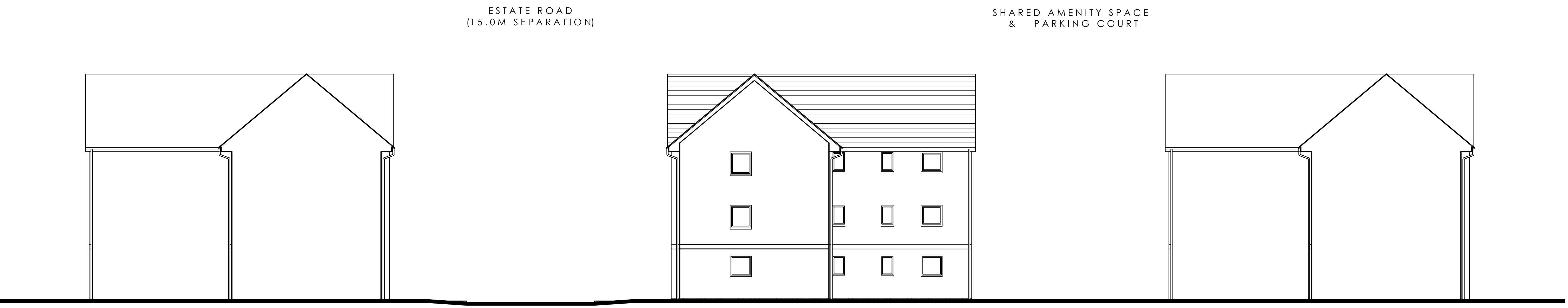

STREET ELEVATION

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 211 CA Notional Street Elevation

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	08.01.24	JD		JM	1:200 @ A3	2740	211(02)101	-

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AREA SCHEDULE

WDQR 2021 Area Requirements	
2 Person 1 Bed Flat (Common Access):	50.0m²
Measured GIA	
Flat 1	46.2m²
Flat 2	48.5m²
Flat 3	47.6m²
WDQR 2021 General Storage Requirements	
2 Person 1 Bed Flat:	1.5m²
GF Store	0.5m²
Airing Cupboard (AC)	0.8m²
Flat 1 Cumulative Total:	**1.3m²**
GF Store	0.6m²
Airing Cupboard (AC)	1.0m²
Flat 2 Cumulative Total:	**1.6m²**
GF Store	0.4m²
Airing Cupboard (AC)	1.1m²
Flat 3 Cumulative Total:	**1.5m²**

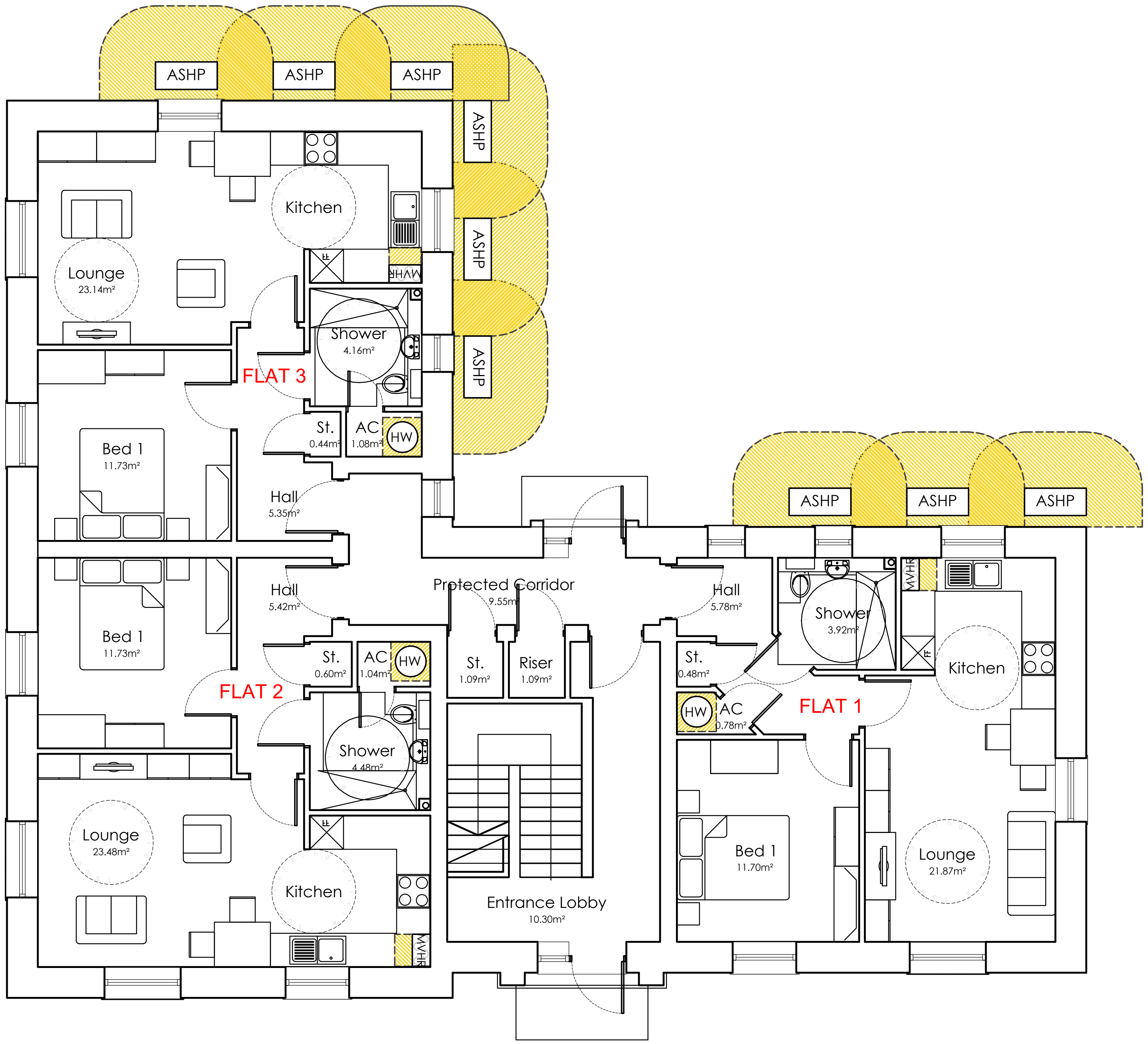
MEP & PLANT PROVISIONS

Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

CONSTRUCTIONS

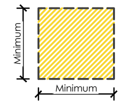
External walls	550mm
Internal walls	100mm
Intermediate floors	400mm

Constructional thicknesses are indicative only & must be coordinated with fabric requirements for acoustic, fire & thermal performances on a site-by-site basis. All TBC by the constructional preferences of the appointed contractor.



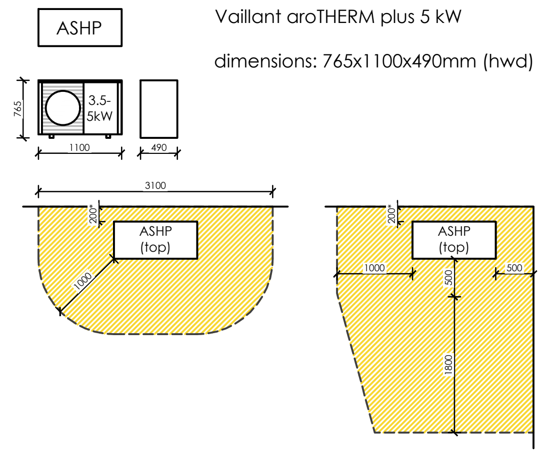
GROUND FLOOR PLAN

LOW CARBON PLANT



Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

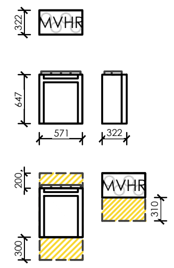


Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)

*Clearance for heating only: +50mm if ASHP provides cooling.

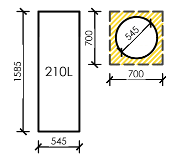
MVHR



envirovent energiSava 200
dimensions: 647x572x322mm (hwd)

Volume flow:	40-245m³/h
Heat recovery:	89.0%
Specific fan power:	0.79W/l/s

Hot Water Cylinder



Mixergy cylinder 150 / 210L

dimensions: 1255 / 1585x545mm (hd)

Mixergy 210L for HT 421

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 211 CA GF Plan

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	08.01.24	JD		JM	1:100 @ A3	2740	211(02)200	-

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AREA SCHEDULE

WDQR 2021 Area Requirements

2 Person 1 Bed Flat (Common Access):	50.0m²

Measured GIA

Flat 4	46.2m²
Flat 5	48.5m²
Flat 6	47.6m²

WDQR 2021 General Storage Requirements

2 Person 1 Bed Flat:	1.5m²
GF Store	0.5m²
Airing Cupboard (AC)	0.8m²
Flat 4 Cumulative Total:	**1.3m²**
GF Store	0.6m²
Airing Cupboard (AC)	1.0m²
Flat 5 Cumulative Total:	**1.6m²**
GF Store	0.4m²
Airing Cupboard (AC)	1.1m²
Flat 6 Cumulative Total:	**1.5m²**

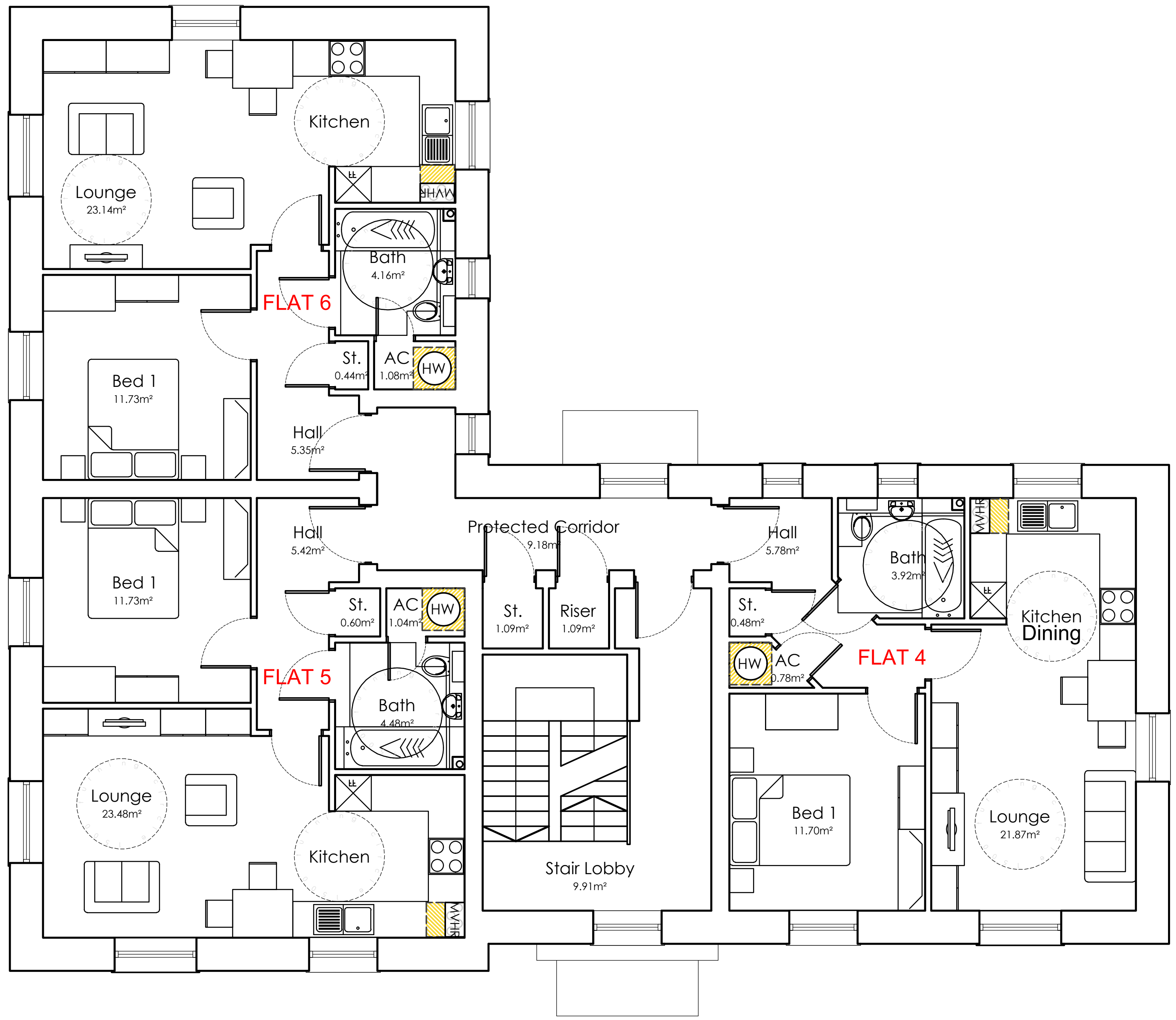
MEP & PLANT PROVISIONS

Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

CONSTRUCTIONS

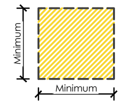
External walls	550mm
Internal walls	100mm
Intermediate floors	400mm

Constructional thicknesses are indicative only & must be coordinated with fabric requirements for acoustic, fire & thermal performances on a site-by-site basis. All TBC by the constructional preferences of the appointed contractor.



FIRST FLOOR PLAN

LOW CARBON PLANT

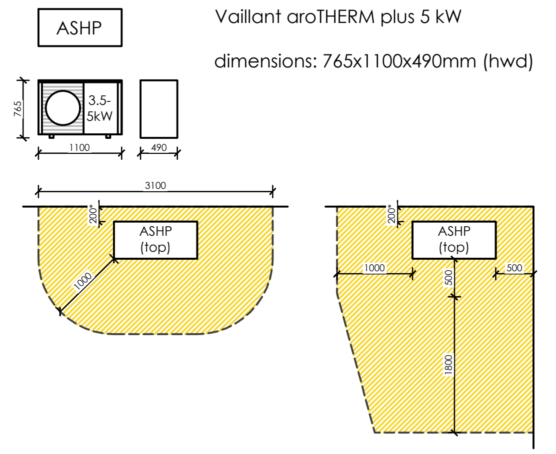


Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

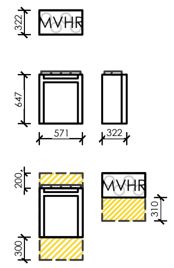
Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

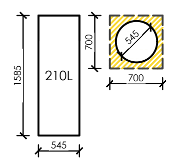
MVHR



envirovent energiSava 200
dimensions: 647x572x322mm (hwd)

Volume flow:	40-245m³/h
Heat recovery:	89.0%
Specific fan power:	0.79W/l/s

Hot Water Cylinder



Mixergy cylinder 150 / 210L

dimensions: 1255 / 1585x545mm (hd)

Mixergy 210L for HT 421

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

A3
Original sheet size

Rev	Date	By	Description

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Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 211 CA 1F Plan

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	08.01.24	JD		JM	1:100 @ A3	2740	211(02)201	-

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AREA SCHEDULE

WDQR 2021 Area Requirements
2 Person 1 Bed Flat (Common Access): 50.0m²

Measured GIA

Flat 7	46.2m²
Flat 8	48.5m²
Flat 9	47.6m²

WDQR 2021 General Storage Requirements
2 Person 1 Bed Flat: 1.5m²

GF Store	0.5m²
Airing Cupboard (AC)	0.8m²
Flat 7 Cumulative Total:	**1.3m²**
GF Store	0.6m²
Airing Cupboard (AC)	1.0m²
Flat 8 Cumulative Total:	**1.6m²**
GF Store	0.4m²
Airing Cupboard (AC)	1.1m²
Flat 9 Cumulative Total:	**1.5m²**

MEP & PLANT PROVISIONS

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CONSTRUCTIONS

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Internal walls	100mm
Intermediate floors	400mm

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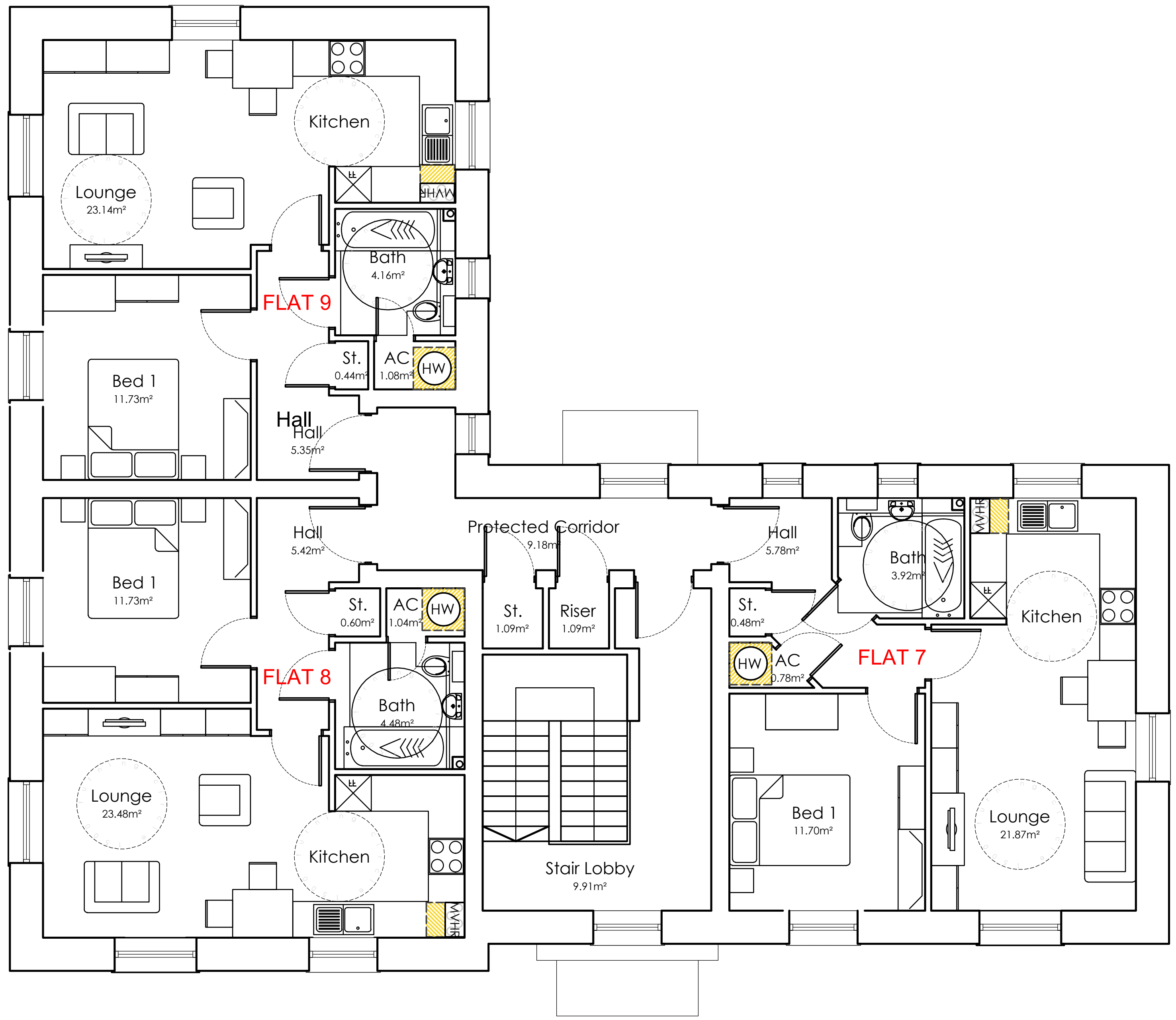
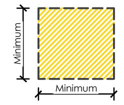


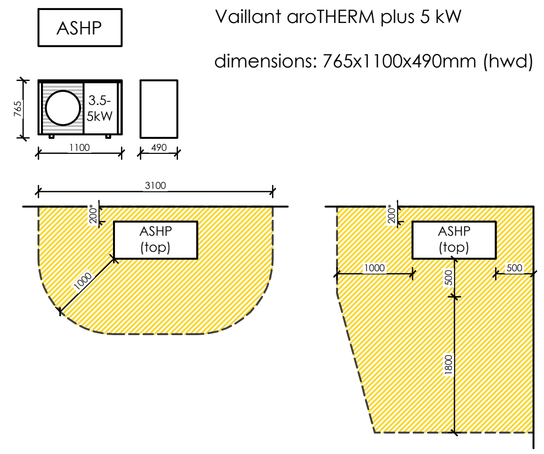
SECOND FLOOR PLAN

LOW CARBON PLANT



Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

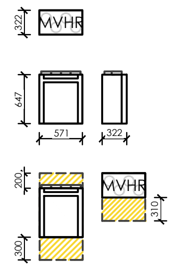


Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)

*Clearance for heating only: +50mm if ASHP provides cooling.

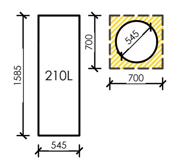
MVHR



envirovent energiSava 200
dimensions: 647x572x322mm (hwd)

Volume flow:	40-245m³/h
Heat recovery:	89.0%
Specific fan power:	0.79W/l/s

Hot Water Cylinder



Mixergy cylinder 150 / 210L

dimensions: 1255 / 1585x545mm (hd)

Mixergy 210L for HT 421

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 211 CA 2F Plan

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	08.01.24	JD		JM	1:100 @ A3	2740	211(02)202	-

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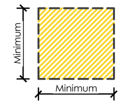
FRONT ELEVATION

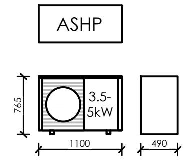
LEFT ELEVATION

LOW CARBON PLANT



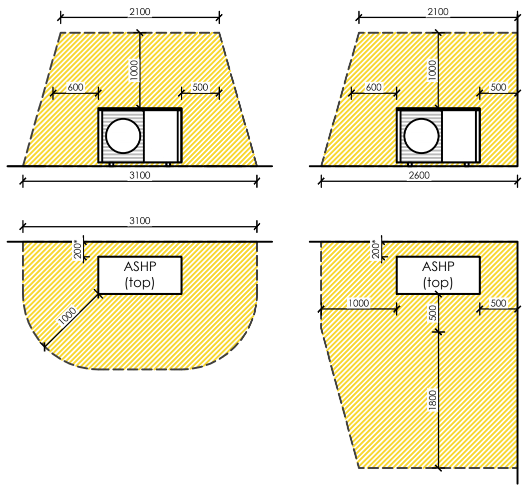
Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP



Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 211 CA Elevations Front & Left

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	09.01.24	JD		JM	1:100 @ A3	2740	211(02)300	-

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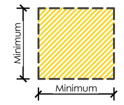
REAR ELEVATION

RIGHT ELEVATION

LOW CARBON PLANT



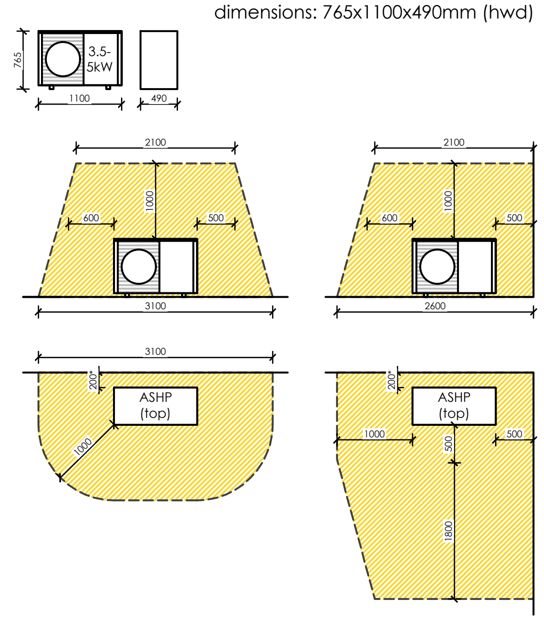
Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

ASHP

Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

A3
Original sheet size

Rev	Date	By	Description

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Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 211 CA Elevations Rear & Right

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	09.01.24	JD		JM	1:100 @ A3	2740	211(02)301	-

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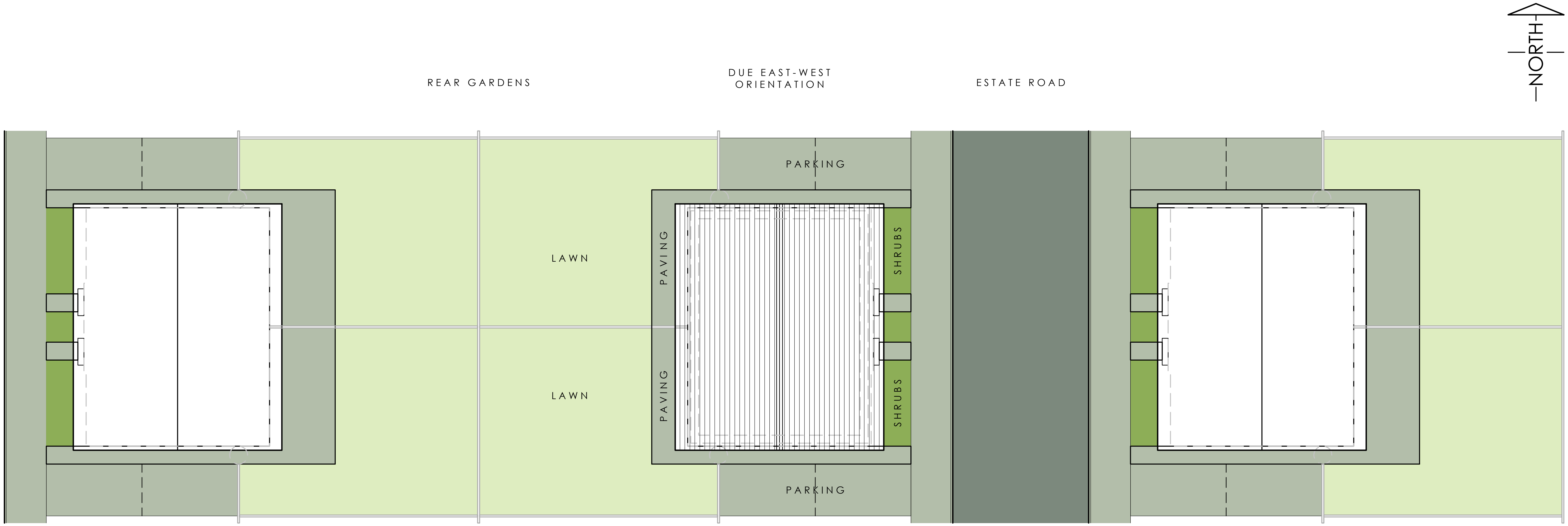
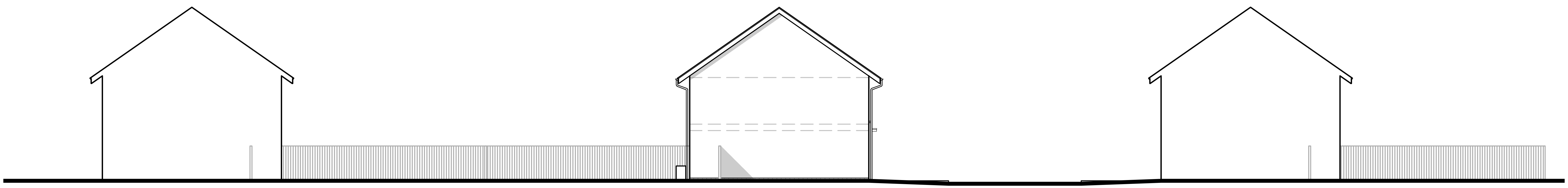


NOTIONAL SITE LAYOUT



STREET ELEVATION

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 421 Notional Site Layout

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	08.01.24	JD		JM	1:200 @ A3	2740	421(02)200	-

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e:mail@spring-consultancy.co.uk

AREA SCHEDULE

WDQR 2021 Area Requirements
4 Person 2 Bed House: 83.0m²

Measured GIA: **83.2m²**

WDQR 2021 General Storage Requirements
4 Person 2 Bed House: 2.5m²

GF Store	1.0m²
FF Store	0.9m²
Airing Cupboard (AC)	1.0m²
Cumulative Total:	**2.9m²**

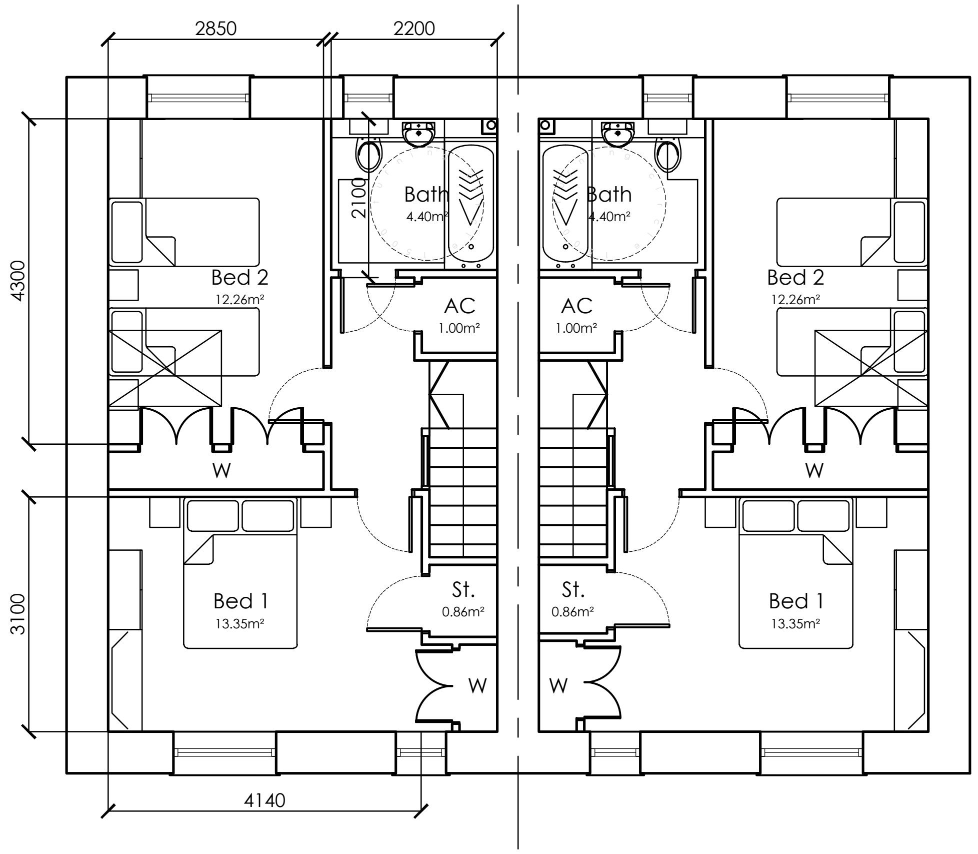
MEP & PLANT PROVISIONS

Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

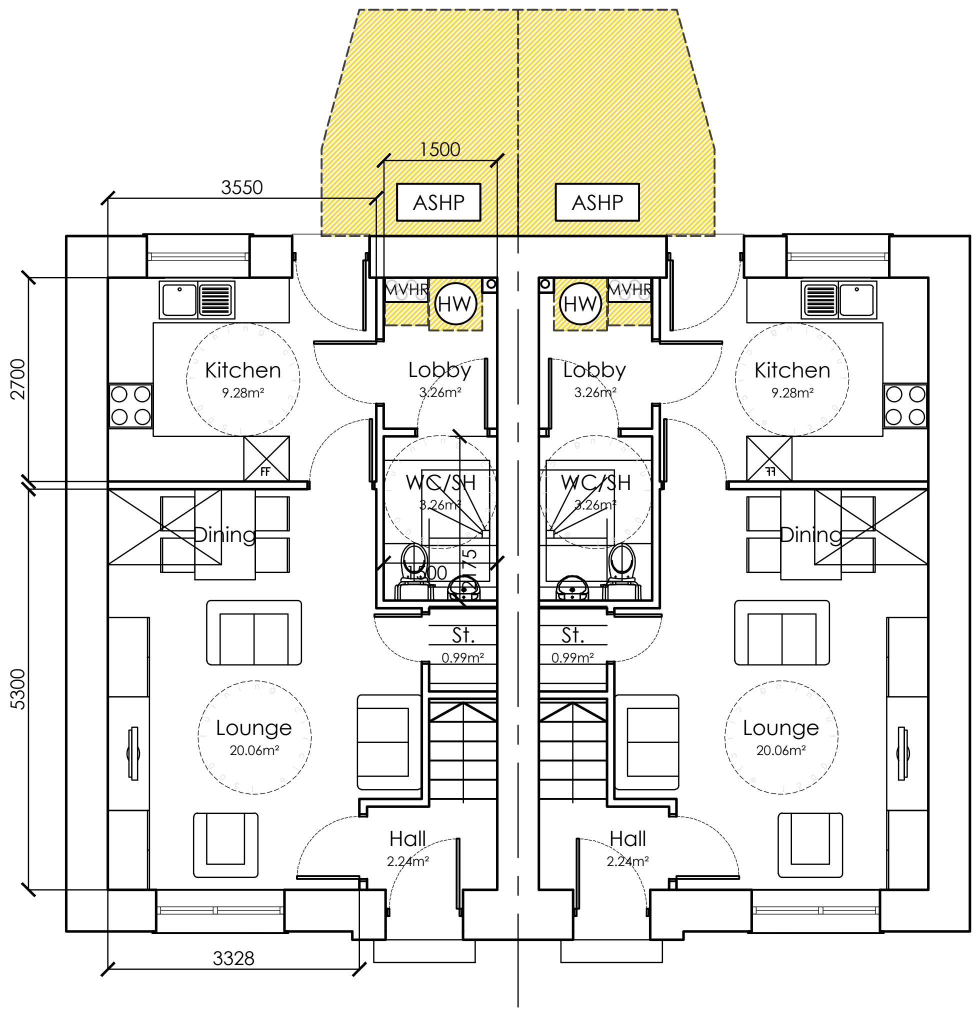
CONSTRUCTIONS

External walls	550mm
Internal walls	100mm
Intermediate floors	400mm

Constructional thicknesses are indicative only & must be coordinated with fabric requirements for acoustic, fire & thermal performances on a site-by-site basis. All TBC by the constructional preferences of the appointed contractor.

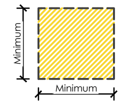


FIRST FLOOR PLAN



GROUND FLOOR PLAN

LOW CARBON PLANT

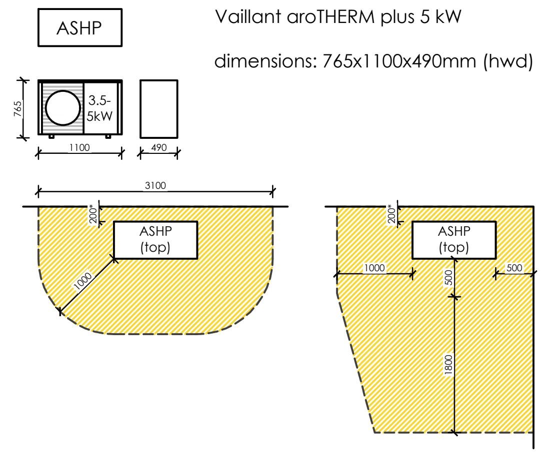


Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

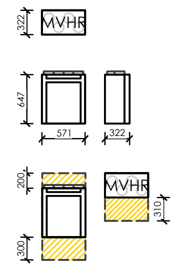
Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

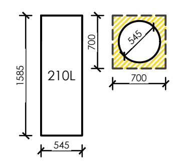
MVHR



envirovent energiSava 200
dimensions: 647x572x322mm (hwd)

Volume flow:	40-245m³/h
Heat recovery:	89.0%
Specific fan power:	0.79W/l/s

Hot Water Cylinder



Mixergy cylinder 150 / 210L

dimensions: 1255 / 1585x545mm (hd)

Mixergy 210L for HT 421

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 421 Floor Plans

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	21.12.23	JD		JM	1:100 @ A3	2740	421(02)200	-

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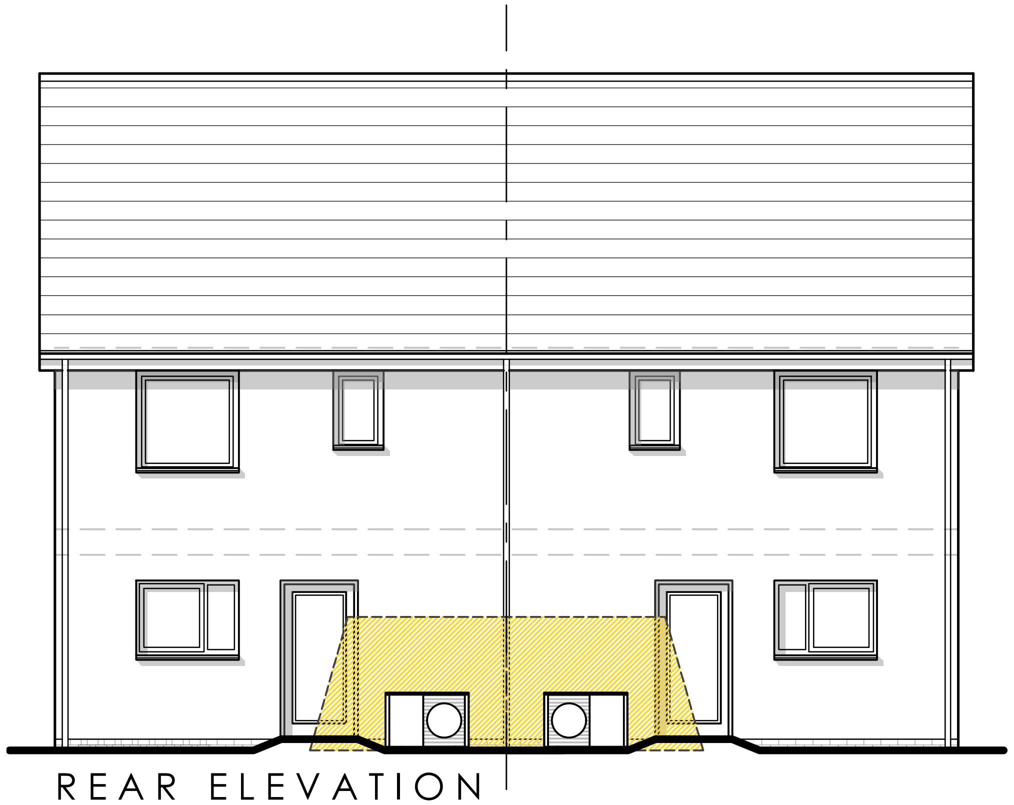
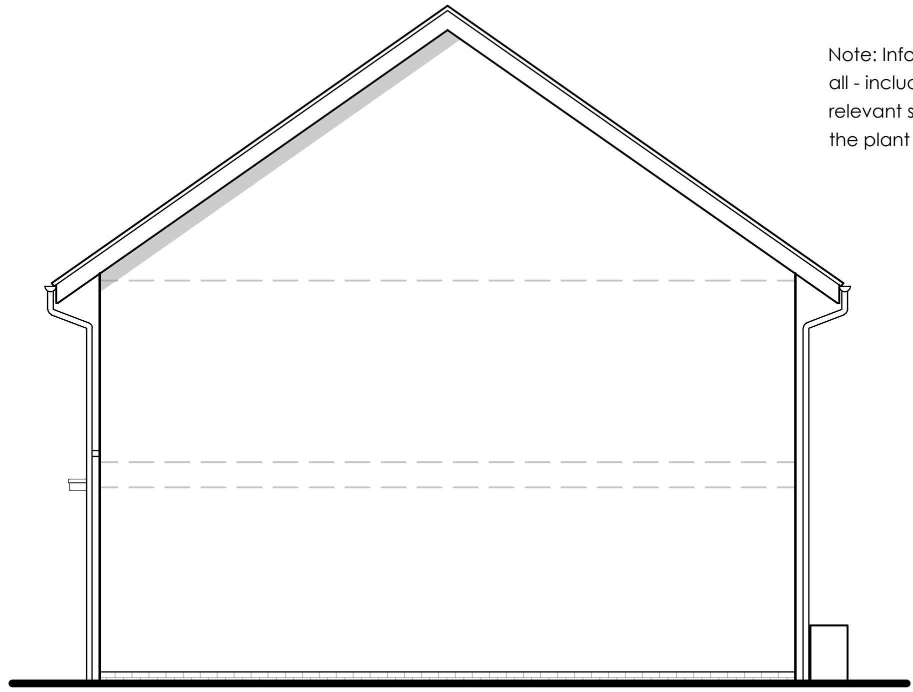
t: 01656 656267 e:mail@spring-consultancy.co.uk

FRONT ELEVATION

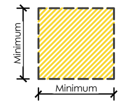


REAR ELEVATION



SIDE ELEVATION

LOW CARBON PLANT

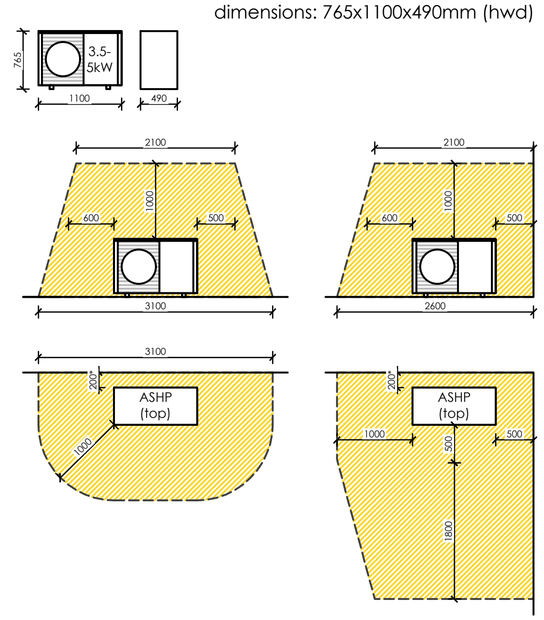


Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 421 Elevations

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	21.12.23	JD		JM	1:100 @ A3	2740	421(02)300	-

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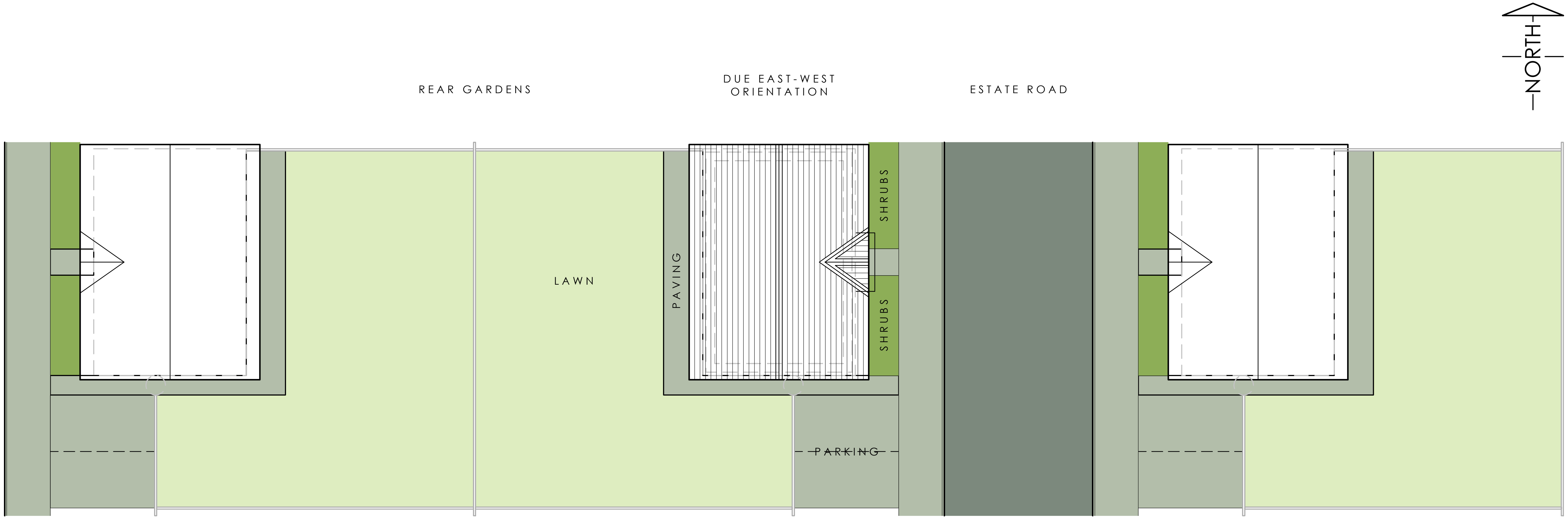
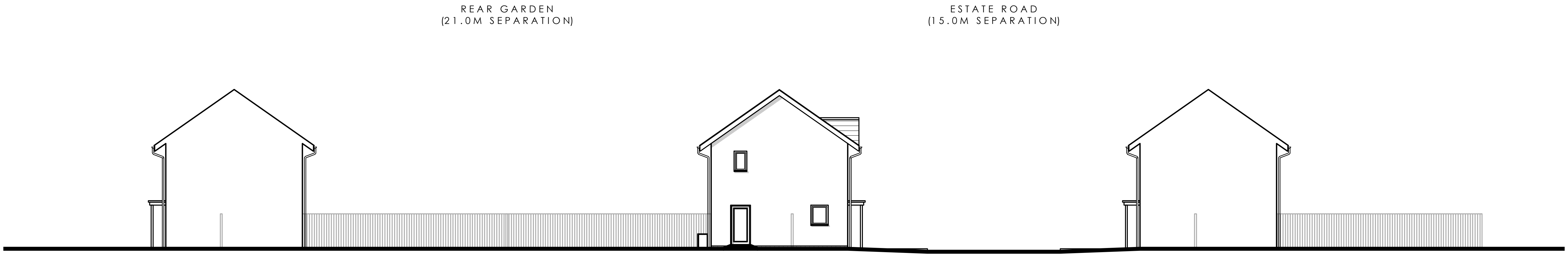


NOTIONAL SITE LAYOUT



STREET ELEVATION

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 641 Floor Plans

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	04.01.24	JD		JM	1:100 @ A3	2740	641(02)200	-

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AREA SCHEDULE

WDQR 2021 Area Requirements	
6 Person 4 Bed House:	110.0m²
Measured GIA:	**110.4m²**
WDQR 2021 General Storage Requirements	
6 Person 4 Bed House:	3.0m²
GF Store	2.4m²
Airing Cupboard (AC)	0.9m²
Cumulative Total:	**3.3m²**

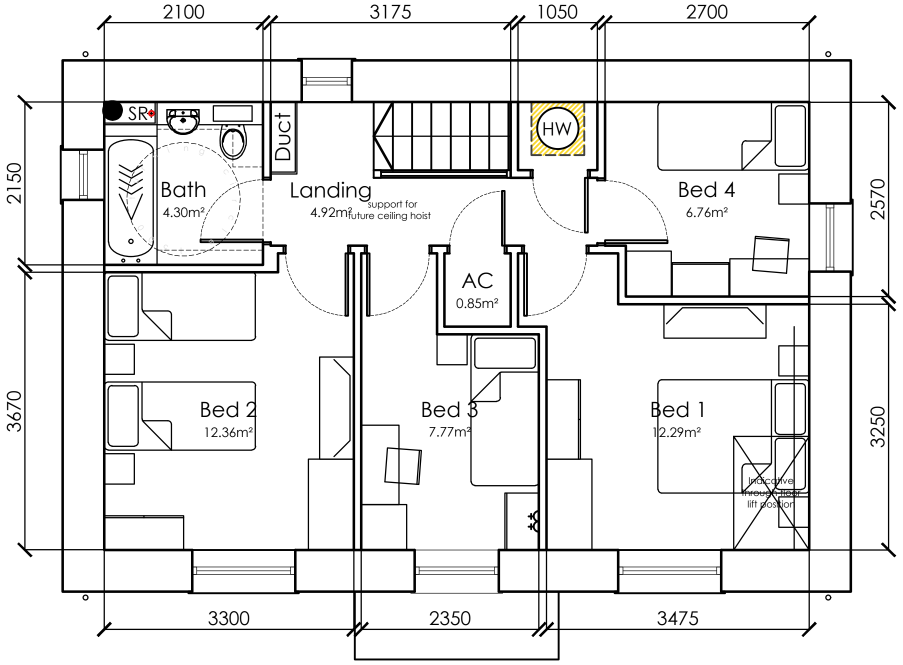
MEP & PLANT PROVISIONS

Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

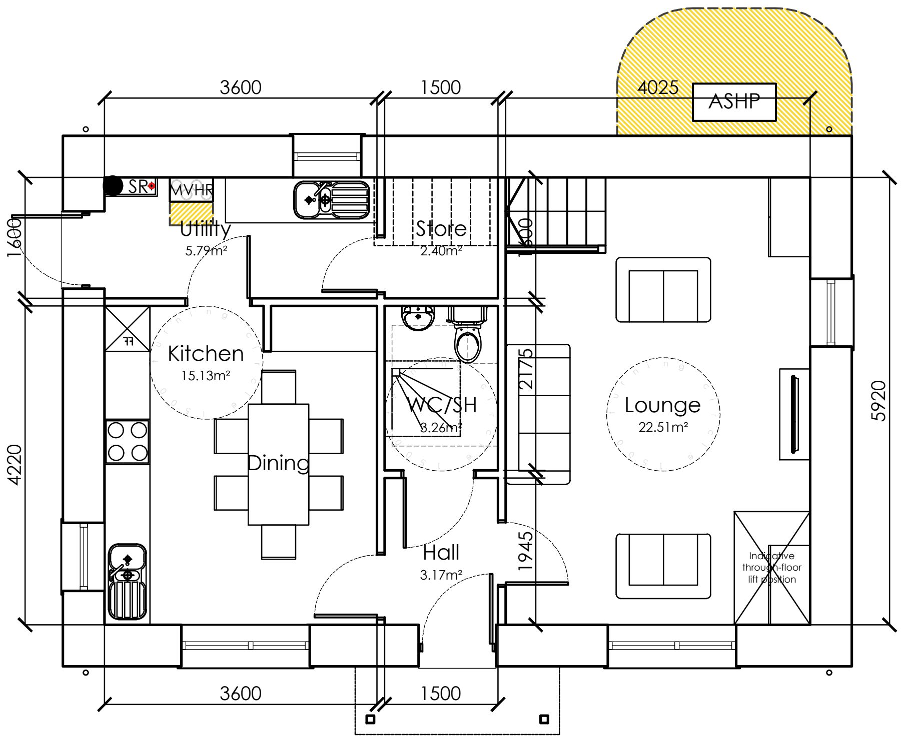
CONSTRUCTIONS

External walls	550mm
Internal walls	100mm
Intermediate floors	400mm

Constructional thicknesses are indicative only & must be coordinated with fabric requirements for acoustic, fire & thermal performances on a site-by-site basis. All TBC by the constructional preferences of the appointed contractor.

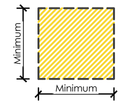


FIRST FLOOR PLAN



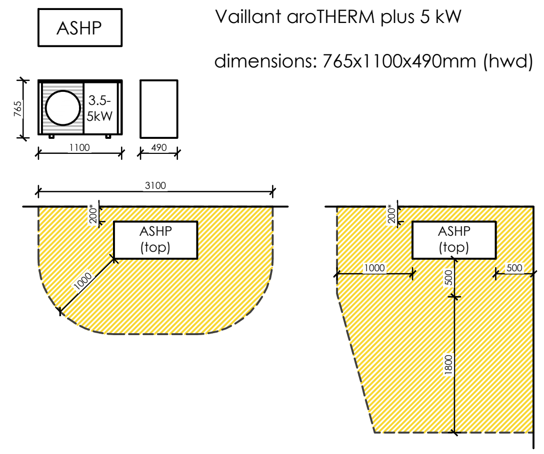
GROUND FLOOR PLAN

LOW CARBON PLANT



Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

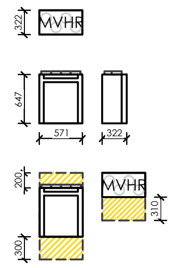


Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)

*Clearance for heating only: +50mm if ASHP provides cooling.

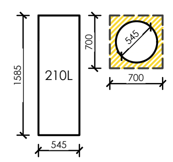
MVHR



envirovent energiSava 200
dimensions: 647x572x322mm (hwd)

Volume flow:	40-245m³/h
Heat recovery:	89.0%
Specific fan power:	0.79W/l/s

Hot Water Cylinder



Mixergy cylinder 150 / 210L

dimensions: 1255 / 1585x545mm (hd)

Mixergy 210L for HT 421

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 641 Floor Plans

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	04.01.24	JD		JM	1:100 @ A3	2740	641(02)200	-

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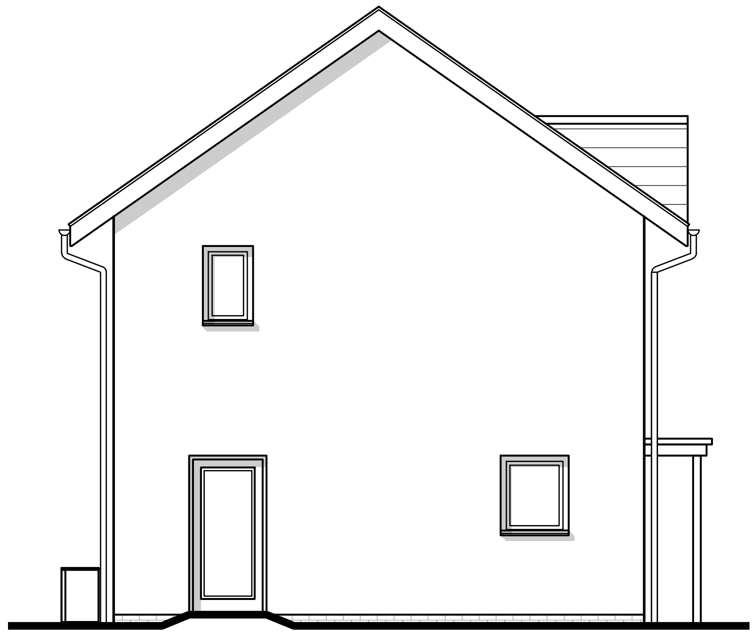
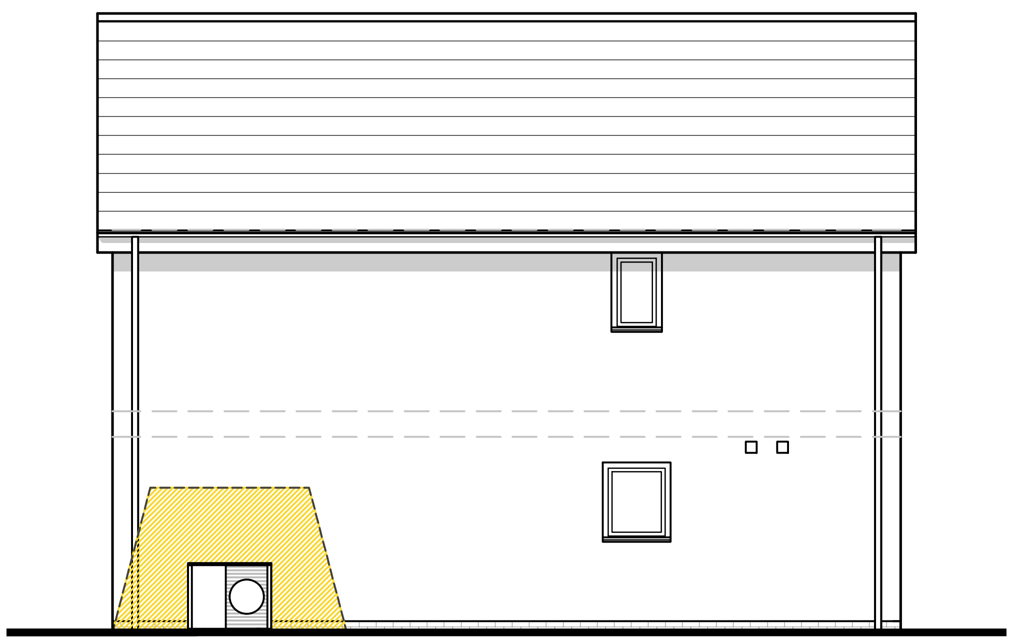
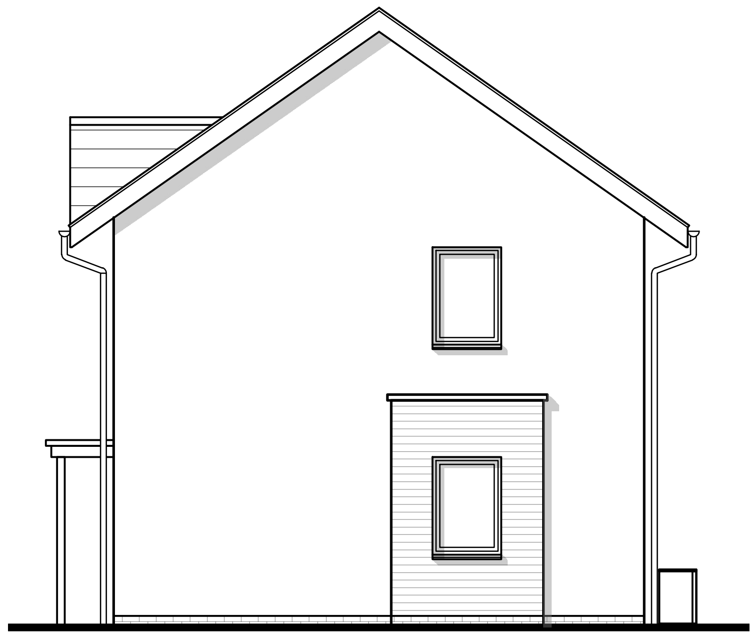
FRONT ELEVATION



LEFT SIDE ELEVATION

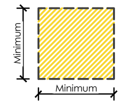


REAR ELEVATION



RIGHT SIDE ELEVATION

LOW CARBON PLANT

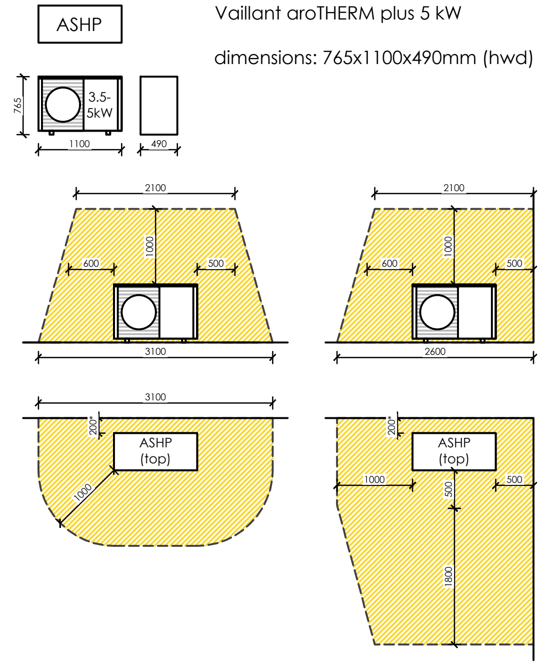


Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	HT 641 Elevations

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	21.12.23	JD		JM	1:100 @ A3	2740	641(02)300	-

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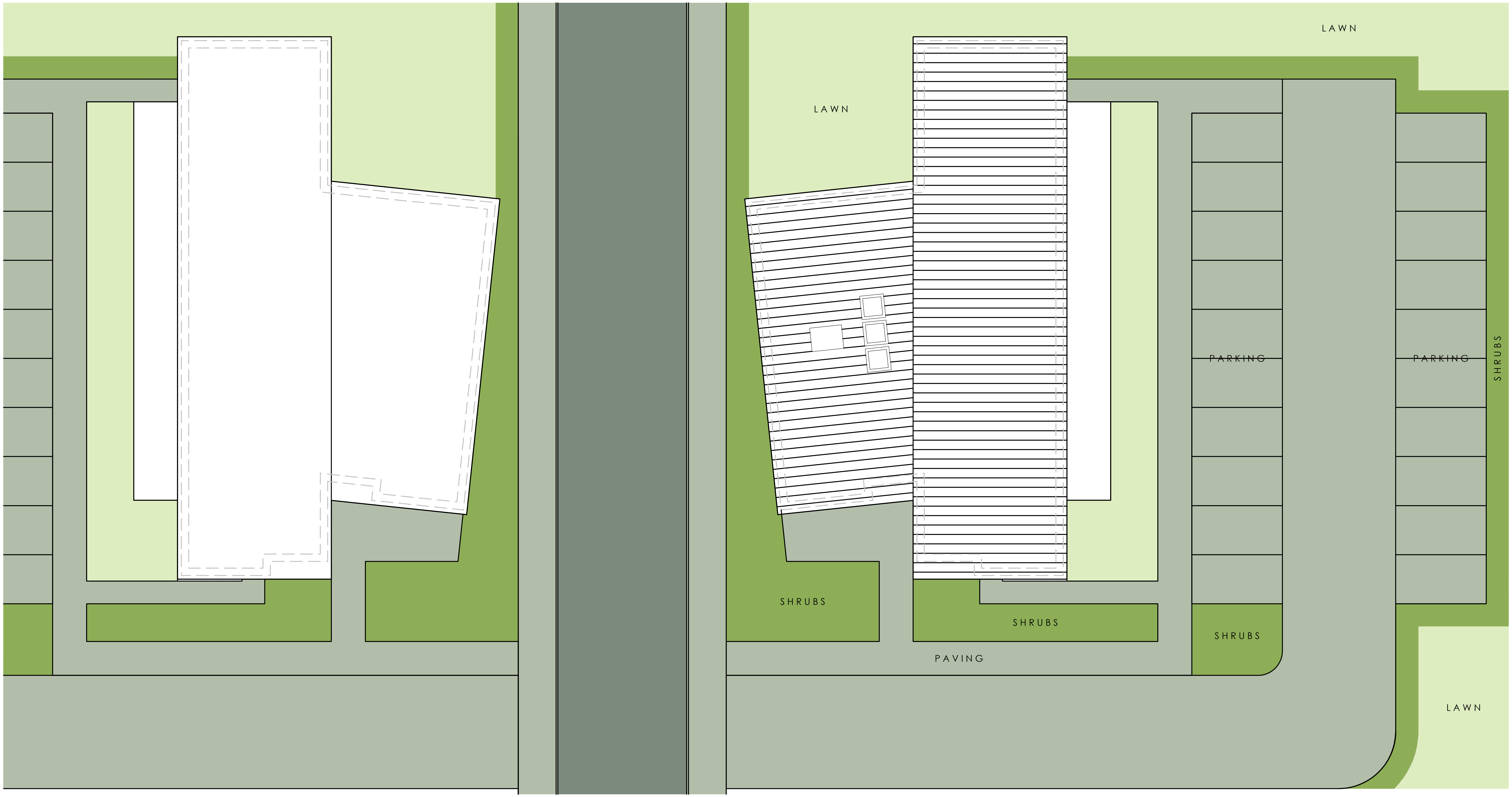

NOTIONAL SITE LAYOUT

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	OF 315 Notional Site Layout

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	06.02.24	JD		JM	1:200 @ A3	2740	315(02)100	-

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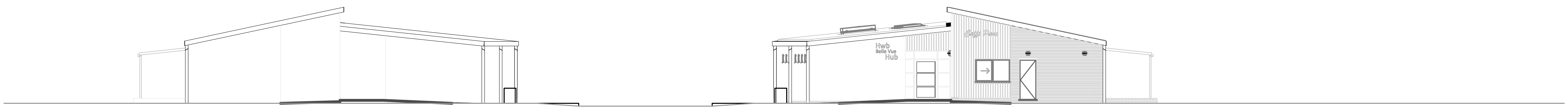
HIGHWAY
(13.5M SEPARATION)

SHARED AMENITY SPACE
& PARKING COURT



STREET ELEVATION

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	OF 315 Notional Street Elevation

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	07.02.24	JD		JM	1:200 @ A3	2740	315(02)101	-

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Unit 2 Chapel Barns | Merthyr Mawr | Bridgend | CF32 0LS
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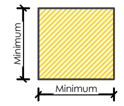
LOW CARBON PLANT

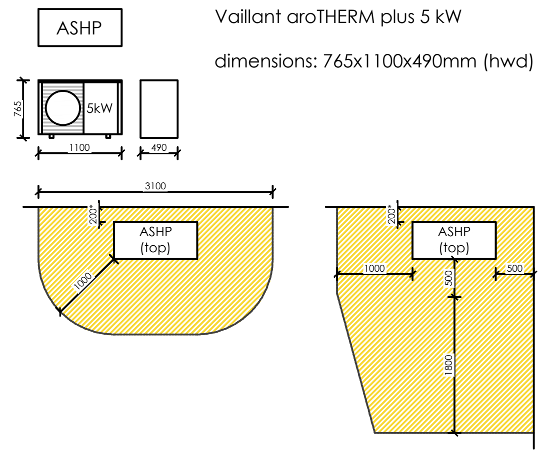


Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

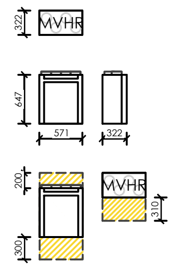
Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

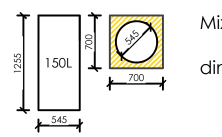
MVHR



envirovent energiSava 200
dimensions: 647x572x322mm (hwd)

Volume flow: 40-245m³/h
Heat recovery: 89.0%
Specific fan power: 0.79W/l/s

Hot Water Cylinder



Mixergy cylinder 150L

dimensions: 1255x545mm (hd)

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

CONSTRUCTIONS

External walls	550mm
Internal walls	100mm
Intermediate floors	400mm

Constructional thicknesses are indicative only & must be coordinated with fabric requirements for acoustic, fire & thermal performances on a site-by-site basis. All TBC by the constructional preferences of the appointed contractor.

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	OF 315 GF Plan

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	06.02.24	JD		JM	1:100 @ A3	2740	315(02)201	-

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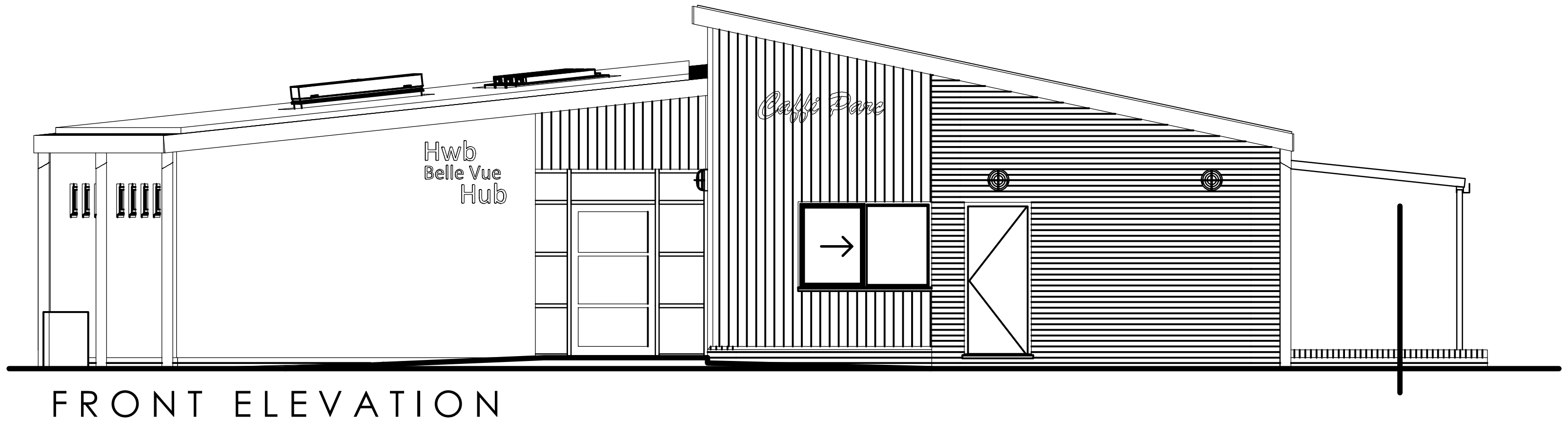
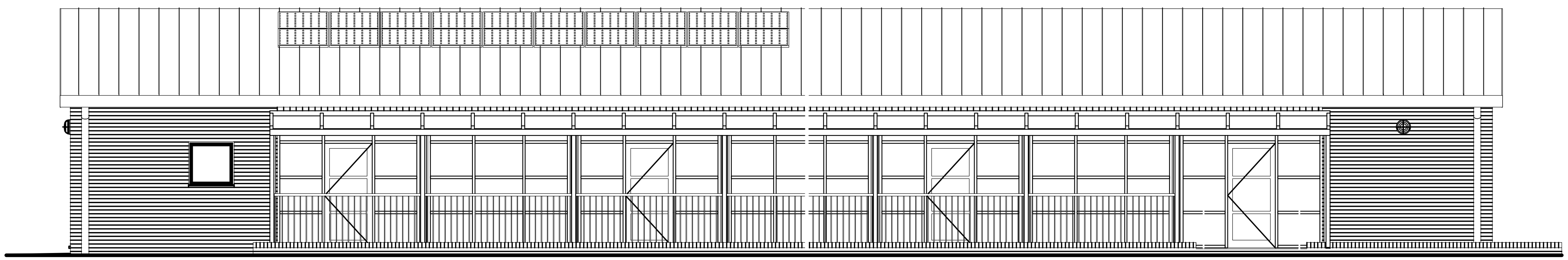
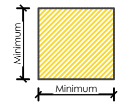


FRONT ELEVATION



RIGHT ELEVATION

LOW CARBON PLANT

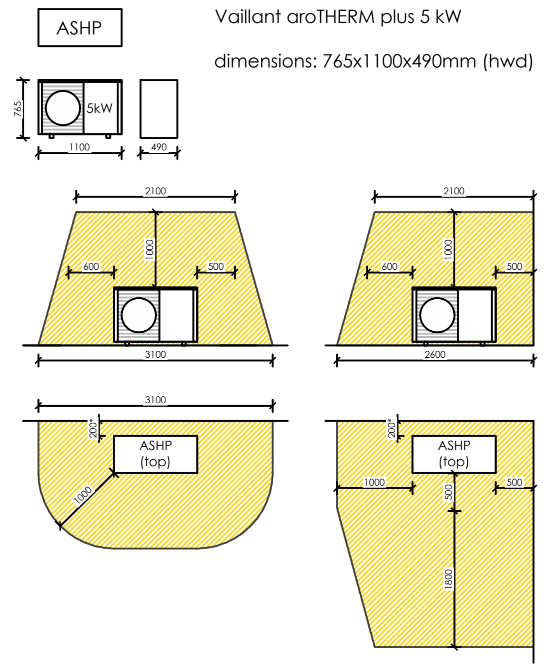


Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

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A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	OF 315 Elevations Front & Right

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	06.02.24	JD		JM	1:100 @ A3	2740	211(02)300	-

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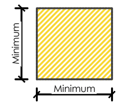
LOW CARBON PLANT

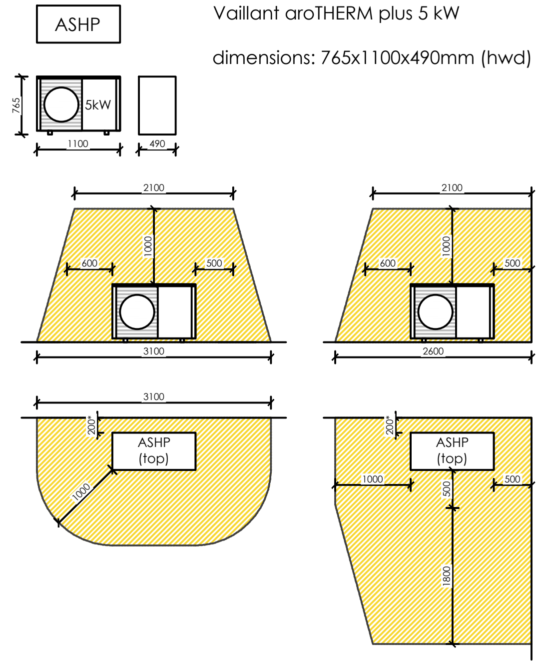


Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

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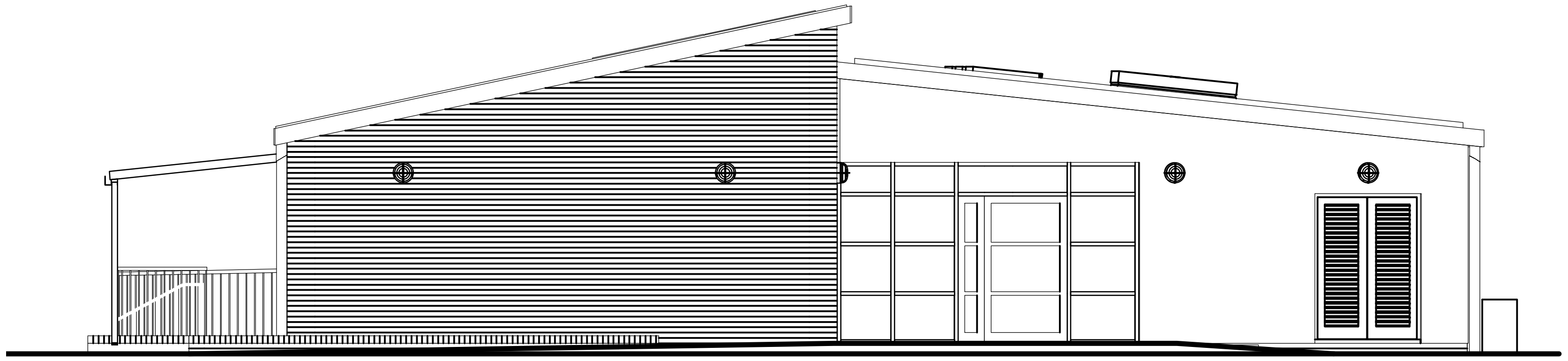
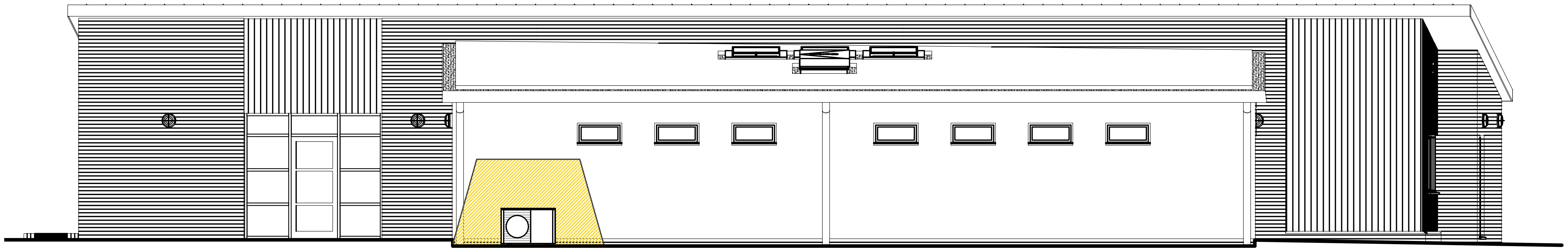


REAR ELEVATION



LEFT ELEVATION

A3
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	OF 315 Elevations Rear & Left

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	06.02.24	JD		JM	1:100 @ A3	2740	211(02)301	-

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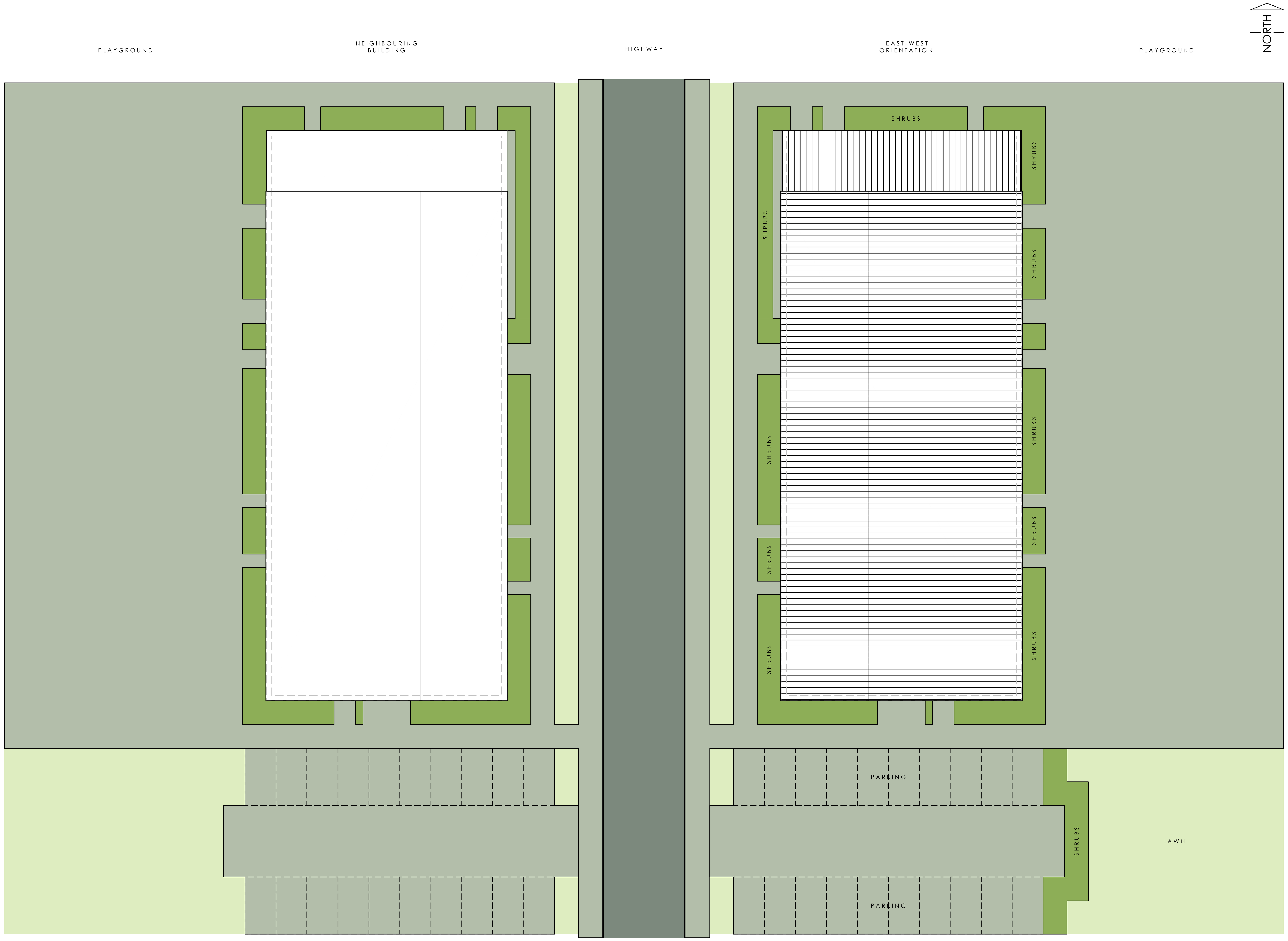
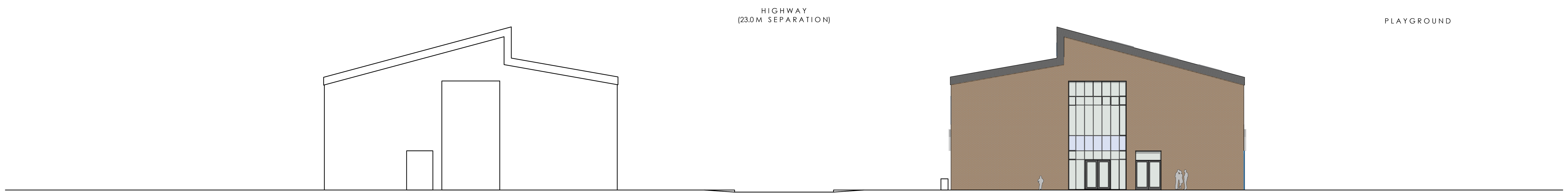
e:mail@spring-consultancy.co.uk



NOTIONAL SITE LAYOUT



NOTIONAL STREET ELEVATION

A1
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	SC 1492 Notional Site Layout

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	17.04.24	JD		JM	1:200 @ A3	2740	1492(02)100	-

spring design
Unit 2 Chapel Barns | Merthyr Mawr | Bridgend | CF32 0LS
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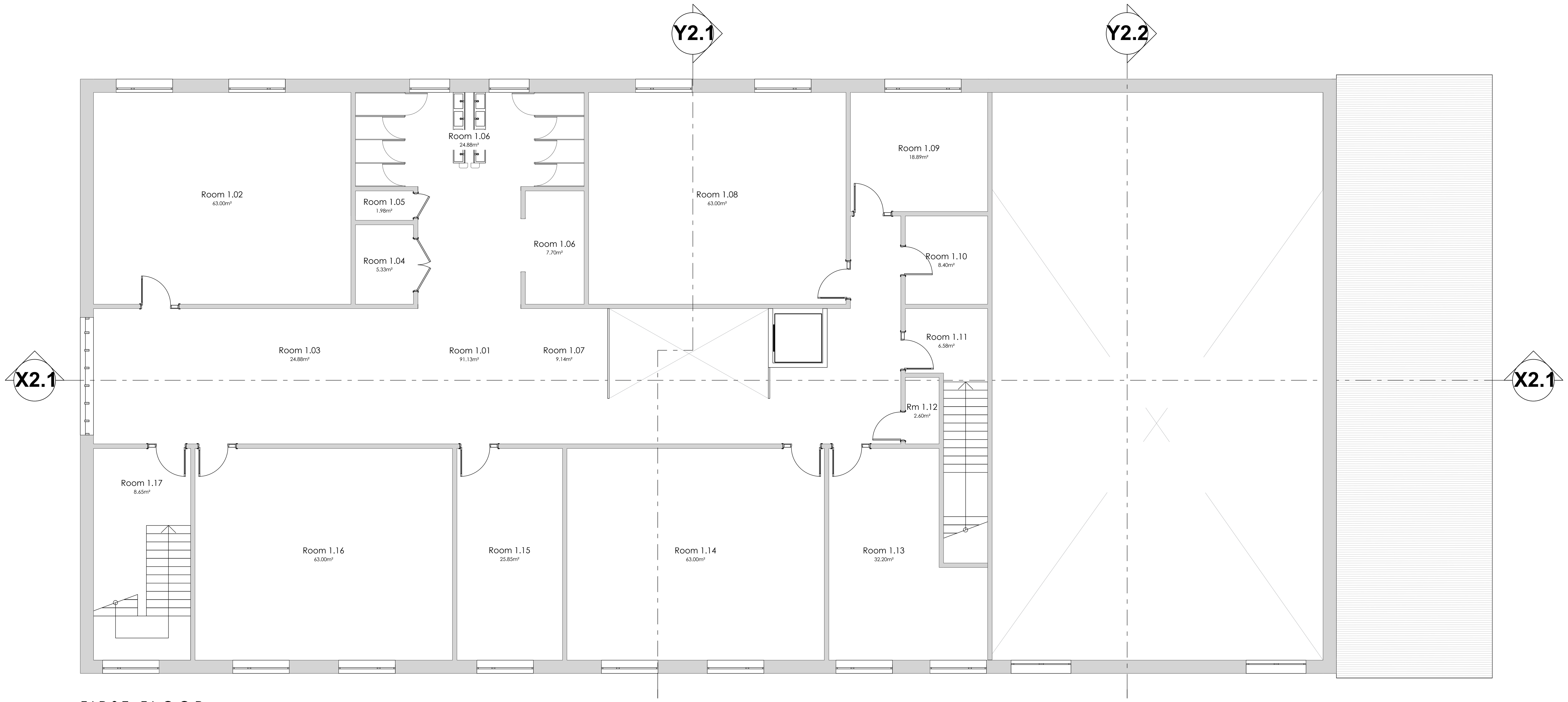
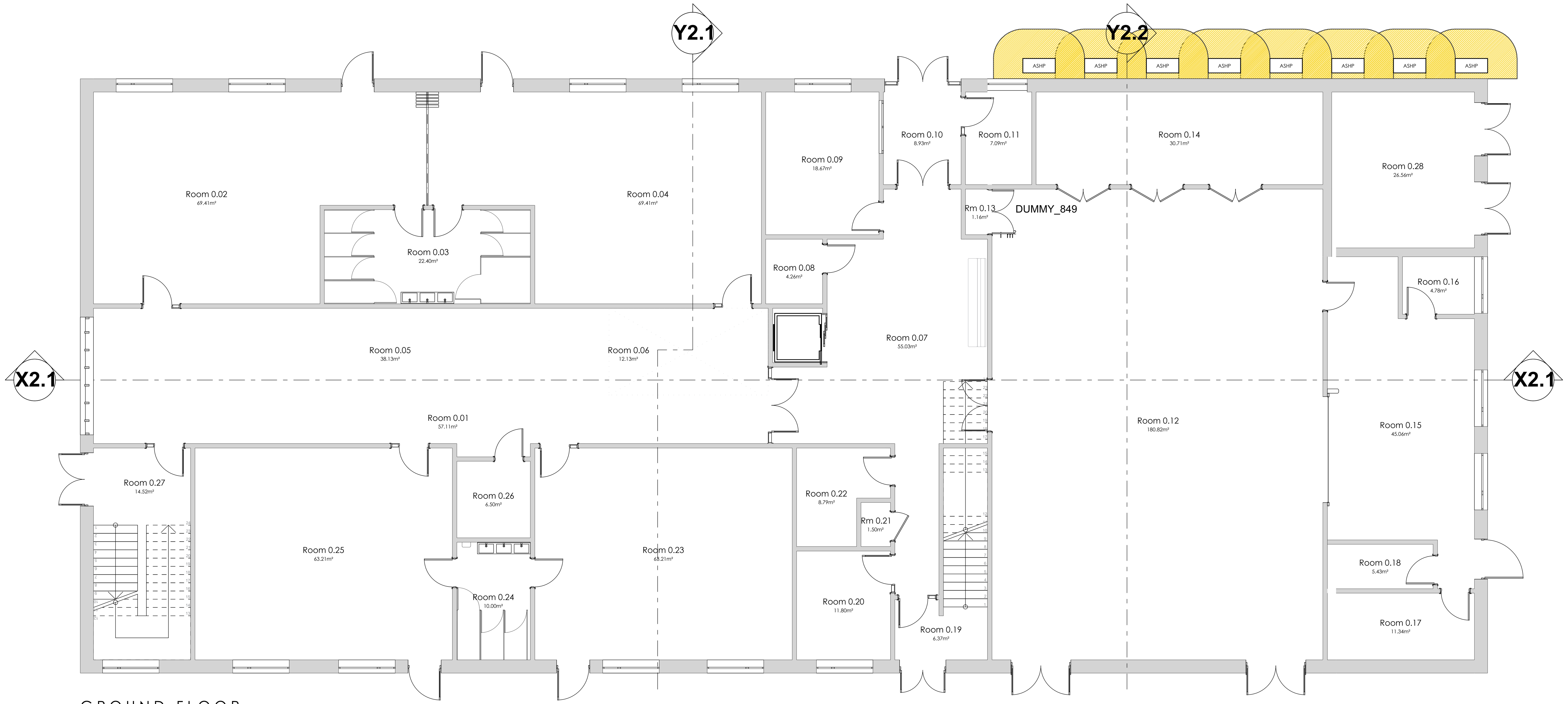
e:mail@spring-consultancy.co.uk



FIRST FLOOR



GROUND FLOOR

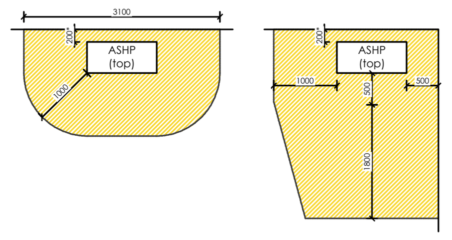
LOW CARBON PLANT

Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP

Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

MVHR

envirovent energiSava 200
dimensions: 647x572x322mm (hwd)

Volume flow:	40-245m³/h
Heat recovery:	89.0%
Specific fan power:	0.79W/l/s

Hot Water Cylinder

Mixergy cylinder 150L

dimensions: 1255x545mm (hd)

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

CONSTRUCTIONS

External walls	550mm
Internal walls	100mm
Intermediate floors	400mm

Constructional thicknesses are indicative only & must be coordinated with fabric requirements for acoustic, fire & thermal performances on a site-by-site basis. All TBC by the constructional preferences of the appointed contractor.

A1
Original sheet size

Rev	Date	By	Description

Client: Vale of Glamorgan Council

Project: Net Zero Carbon Buildings Technical Feasibility

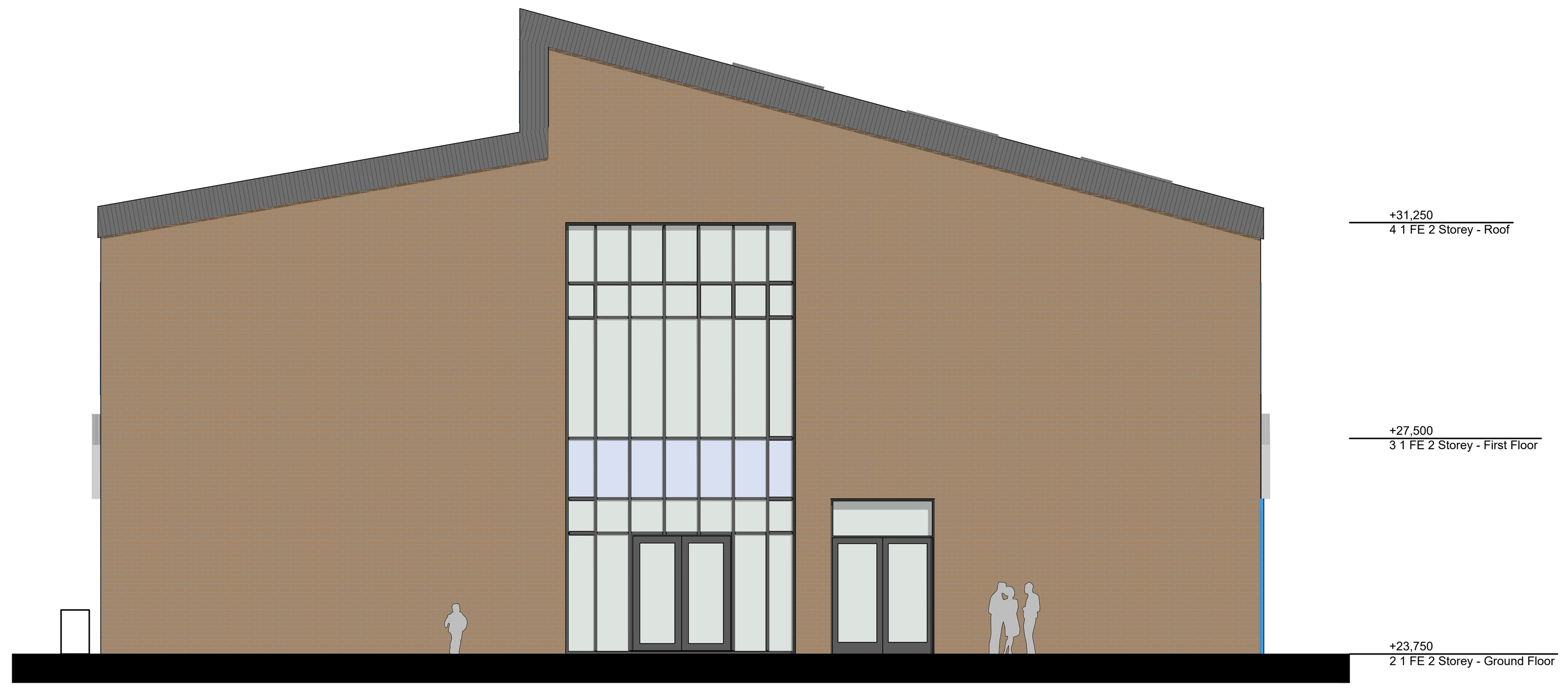
Drawing Title: SC 1492 Floor Plans

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	17.04.24	JD		JM	1:100 @ A1	2740	1492(02)200	-

spring design
Unit 2 Chapel Barns | Merthyr Mawr | Bridgend | CF32 0LS
t: 01656 656267
e:mail@spring-consultancy.co.uk

EAST ELEVATION

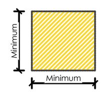
NORTH ELEVATION



SOUTH ELEVATION

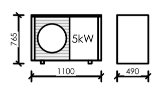
WEST ELEVATION

LOW CARBON PLANT



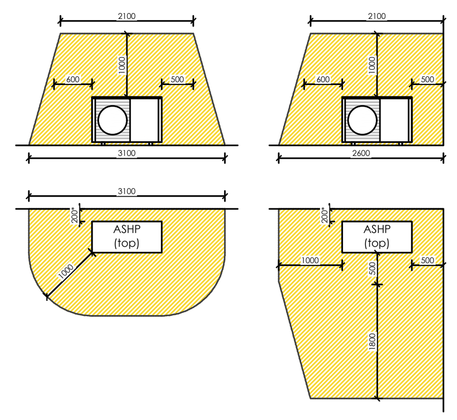
Dimensions denote minimum installation & maintenance clearances, extrapolated to hatched areas. All as defined by manufacturer's requirements, refer to product literature for specifics.

ASHP



Vaillant aroTHERM plus 5 kW

dimensions: 765x1100x490mm (hwd)



*Clearance for heating only: +50mm if ASHP provides cooling.

Note: Information presented indicatively for coordination with all - including manufacturer & model specification - TBC by relevant specialist consultant / subcontractor. All revisions to the plant specification must be reported for coordination.

A1
Original sheet size

Rev	Date	By	Description

Client:	Project:	Drawing Title:
Vale of Glamorgan Council	Net Zero Carbon Buildings Technical Feasibility	SC 1492 Elevations

Drawing Status:	Date:	Drawn By:	Checked:	Director:	Scale:	Job No:	Drawing No.	Rev.
FEASIBILITY	17.04.24	JD		JM	1:100 @ A1	2740	1492(02)300	-

spring design
Unit 2 Chapel Barns | Merthyr Mawr | Bridgend | CF32 0LS
t: 01656 656267
e:mail@spring-consultancy.co.uk

Vale of Glamorgan Council

Net Zero Carbon Buildings Feasibility Study and Cost Assessment

Work Stage 3F

Cost Analysis

June 2024

Revision: B

Architecture
Low Energy Consultancy
Civil Engineering
Structural Engineering
Urban Design

Contents

spring design

Section 1: Introduction

1.1 Introduction

Spring Design Consultancy Limited is appointed to assist Vale of Glamorgan Council in developing suitably evidenced Net Zero policy to guide, assess and determine applications for new-build residential and non-residential development within the emerging Replacement Local Development Plan 2021-2036.

This process has been divided into distinct work stages:

Work Stage 1	A - Policy Review B - Policy Approach C - Evidence Base
Work Stage 2	D - Methodologies E - Technical Feasibility
Work Stage 3	F - Cost Analysis
Work Stage 4	G - Evidence H - Cost Implications I - Scrutiny Skillset
Work Stage 5	Examination

This report summarises the assumptions informing and the results of whole life carbon assessment of Work Stage 3F - Cost Analysis.

1.2 Emission Targets

1.2.1 Operational Targets

Operational energy relates to the amount of energy required to operate a building. For this exercise, two measures of operational energy were quantified: Space Heating Demand and Energy Use Intensity (EUI) which both use the metric of kWh/m²/yr.

Space heating demand refers to the amount of energy required to maintain an internal temperature of 20°C or above annually based on Treated Floor Area (TFA). This does not factor in the in-/ efficiencies of the heating system but quantifies the necessary input of heat.

Energy use intensity (EUI) relates to the sum of all energy use by a building on an annual basis based on Gross Internal Area (GIA). This can be delivered via the grid or by on-site renewables and accounts for space heating, hot water, lighting and all unregulated usage in occupation (e.g. all appliance usage) - factoring in system in/ efficiencies - but excludes EV charging.

Four operational scenarios were agreed with VoGC using identical fabric specifications derived from Approved Document L (Wales) 2022 Appendix E.

Operational emission scenarios		
Reference	Space heating demand	Energy use intensity (EUI)
AD: L (Wales) 2025	N/A	N/A
AECB CarbonLite	40 kWh/m²/yr	75 kWh/m²/yr
B&NES	30 kWh/m²/yr	40 kWh/m²/yr res. 50 kWh/m²/yr non.
LETI	15 kWh/m²/yr	40 kWh/m²/yr res. 50 kWh/m²/yr non.

These generally follow the standards for which they are named, however: in recognition of modelling the worst-case scenarios, EUI targets are slightly relaxed from LETI recommendations. No cooling load has been modelled as passive techniques are integrated.

1.2.2 Embodied Targets

Embodied energy (also embodied carbon or life cycle embodied carbon) refers to the total greenhouse gas emissions and removals associated with materials and construction processes throughout the whole life cycle of an asset including its disposal.

Embodied energy is measured in kg CO_2e/m².

As it has historically received less attention than operational energy, no specific targets were set for embodied energy. Instead, it was considered more appropriate to establish what current practice achieves and use this as a baseline to leverage improvements.

Identical u-values were targeted for all operational scenarios with changes concentrated in the quality of the design and construction (improved airtightness and thermal bridge mitigation), quality of external door and window specification and the optimisation of heating and ventilation technologies.

Four scenarios were agreed with VoGC to represent the residential and non-residential typologies.

Embodied emission scenarios		
Reference	Residential	Non-Residential
Masonry	Masonry with PIR	
Framed	140mm Stud with Mineral Wool & PIR	Steel Frame with PIR Panels
Timber	140mm Stud with Woodfibre	
Timber Optimised	Twin Stud Cellulose	

Inclusions and exclusions for embodied outputs vary slightly between different assessment methodologies (e.g. upfront, WLCA, LETI, RIBA, etc.).

1.3 Glossary

1.3.1 Carbon Definitions

Clarity and consistency in the basic terminology used to discuss carbon and Net Zero is key to ensuring meaningful outcomes.

Carbon Definitions for the Built Environment, Buildings and Infrastructure: Improving Consistency in Whole Life Carbon Assessment and Reporting (2023) is a collaboration between professions throughout the construction industry including the Chartered Institute of Building Service Engineers (CIBSE), Institution of Civil Engineers (ICE), Institution of Structural Engineers (IStructE), Low Energy Transformation Initiative (LETI), Royal Institute of British Architects (RIBA), Royal Institute of Chartered Surveyors (RICS), UK Green Building Council and the Whole Life Carbon Network (WLCN) and applies the following.

Greenhouse Gases (GHG)
often 'carbon emissions' in general usage
'Greenhouse Gases' are constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds.

Whole Life Carbon
'Whole Life Carbon' emissions are the sum total of all asset related GHG emissions and removals, both operational and embodied over the life cycle of an asset including its disposal (Modules: A0-A5; B1-B7; B8 optional; C1-C4, all including biogenic carbon, with A0 assumed to be zero for buildings). Overall Whole Life Carbon asset performance includes separately reporting the potential benefits or loads from future energy or material recovery, reuse, and recycling and from exported utilities (Modules D1, D2).

Embodied Carbon *or* **Life Cycle Embodied Carbon**
'Embodied Carbon' emissions of an asset are the total GHG emissions and removals associated with materials and construction processes throughout the whole life cycle of an asset (Modules A0-A5, B1-B5, C1-C4, with A0 assumed to be zero for buildings).

Upfront Carbon - Buildings
'Upfront Carbon' emissions are the GHG emissions associated with materials and construction processes up to practical completion (Modules A0-A5). Upfront carbon excludes the biogenic carbon sequestered in the installed products at practical completion.

Operational Carbon - Energy, Buildings
'Operational Carbon - Energy' (Module B6) are the GHG emissions arising from all energy consumed by an asset in-use, over its life cycle.

Carbon Sequestration
'Carbon Sequestration' is the process by which carbon dioxide is removed from the atmosphere and stored within a material - e.g. stored as 'Biogenic Carbon' in 'Biomass' by plants/ trees through photosynthesis and other processes.

Biogenic Carbon
'Biogenic Carbon' refers to the carbon removals associated with carbon sequestration into biomass as well as any emissions associated with this sequestered carbon. Biogenic carbon must be reported separately if reporting only upfront carbon but should be included in the total if reporting embodied carbon or whole life carbon.

These definitions only address the GHGs with Global Warming Potential assigned by the Intergovernmental Panel on Climate Change (IPCC). A0 is generally assumed to be zero for buildings.

1.3.2 Net Zero Definitions

Net Zero (whole life) Carbon
A 'Net Zero (whole life) Carbon' Asset is one where the sum total of all asset related GHG emissions, both operational and embodied, over an asset's life cycle (Modules A0-A5, B1–B8, C1-C4) are minimized, which meets local carbon, energy and water targets or limits, and with residual 'offsets', equals zero.

To meet the requirements of 'Net Zero (whole life) Carbon' the definitions for 'Net Zero Upfront Carbon', Net Zero Embodied Carbon', 'Net Zero Capital Carbon', Net Zero operational Carbon - Energy', 'Net Zero Operational Carbon - Infrastructure', 'Net Zero In-Use Carbon Asset' and 'Net Zero Operational Carbon - Water' must also be individually met as applicable.

Net Zero Carbon Embodied Carbon *or*
Net Zero Life Cycle Embodied Carbon
A 'Net Zero Embodied Carbon' asset is one where the sum total of GHG emissions and removals over an asset's life cycle (Modules A0-A5, B1-B5 and C1-C4) are minimized, which meets local carbon targets or limits (e.g. kgCO_2e/m²), and with additional 'offsets', equals zero.

Net Zero Upfront Carbon
A 'Net Zero Upfront Carbon' asset is where the sum of GHG emissions, excluding 'biogenic carbon', from Modules A0-A5 is minimized, which meets local carbon targets or limits (e.g. kgCO_2e/m²), and with additional 'offsets', equals zero.

Net Zero Operational Carbon - Energy
A 'Net Zero Operational Carbon - Energy' asset is one where no fossil fuels are used, all energy use Module B6) has been minimized, meets the local energy use target or limit (e.g. kWh/m²/a) and all energy use is generated on- or off- site using renewables that demonstrate additionality. Direct emissions from renewables and any upstream emissions are 'offset'.

Direct emissions must include CH_4 and N_2O emissions from the combustion of biomass and biodiesel fuels. Upstream emissions include: direct and indirect emissions from energy generation and distribution, WTT emissions for energy consumed in the building and from energy generation and distribution.

Net Zero Operational Carbon - Water
A 'Net Zero Operational Carbon - Water' asset is one where water use (Module B7) is minimized, meets local water targets or limits (e.g. litres/person/year) and where those GHG emissions arising from water supply and wastewater treatment are 'offset'.

Net Zero In-Use Asset
A 'Net Zero In-Use Carbon Asset' is one where on an annual basis the sum total of all asset related GHG emissions, both operational and embodied, (Modules B1-B8) are minimized, which meets local carbon, energy and water targets or limits, and with residual 'offsets', equals zero.

Additionality
Procurement of renewable energy for the asset's use which results in new installed renewable energy capacity that otherwise would not have occurred had the intervention not taken place.

Carbon Neutral
All carbon emissions are balanced with offsets based on carbon removals or avoided emissions.

Absolute Zero Carbon
Eliminating all carbon emissions without the use of credits.

1.3.3 Reference Terms

ASHP
Air source heat pump: heating and hot water from electrical source. Efficiency described by COP/ SCOP.

COP/ SCOP
(Seasonal) coefficient of performance: rate of conversion of electricity to useful heat energy.

MEV
Mechanical extract ventilation: constant mechanical extraction from 'wet' rooms (bathroom, kitchen, utility, WC, etc.) with fresh air from trickle vents circulated through the building by depressurisation.

MVHR
Mechanical ventilation with heat recovery: ventilation systems that ensure a constant throughput of fresh, filtered air. 'Waste' heat is transferred from outgoing exhaust air to incoming fresh air to pre-warm it and reduce heating demand.

CO_2e Emissions
Equivalent carbon dioxide emissions calculated using the global warming potential (GWP) of exhaust gases.

Form Factor
Expresses the relationship between the treated floor area and area of the thermal envelope. A better form factor signifies a more efficiently designed building.

Thermal Envelope
The insulated components (floors, walls, ceilings) that separate internal and external volumes. Note this often excludes features such as porches and balconies.

Treated Floor Area (TFA)
The floor area of the rooms within the building that are heated. It excludes the areas of internal partitions, doors, stairs and unusable spaces.

Section 2: Summary

2.1 Executive Summary

As evidenced in Work Stage 2E Technical Feasibility, substantial operational carbon savings are achievable with minor revisions to specifications and embodied carbon reduced without compromising performance.

This report assesses the relative costs associated with constructing buildings to operational Net Zero. Three residential new-build typologies were costed to establish the cost at various scales of development:

- **HT 211** - 3 storey block of nine flats;
- **HT 421** - two semi-detached dwellings;
- **HT 641** - detached single family dwelling.

Four operational scenarios were modelled in PHPP applying identical external envelope u-values to achieve increasing levels of building performance:

- **AD: L (Wales) 2025** - future Building Regulations;
- **AECB CarbonLite** - 40 kWh/m²/yr threshold;
- **B&NES** - 30 kWh/m²/yr threshold;
- **LETI** - 15 kWh/m²/yr threshold.

Cost analysis focused on **AD: L (Wales) 2025**, applying the necessary specification upgrades to achieve **LETI** as the exemplar operational scenario.

Four embodied scenarios were modelled in PHribbon to achieve the **LETI** operational scenario with a range of different constructions:

- **Masonry** - masonry + PIR;
- **Framed** - timber + mineral wool & PIR;
- **Timber** - timber + woodfibre;
- **Timber Optimised** - twin stud timber + cellulose.

Detailed discussion of and cost data for each typology is presented in 3: Cost Analysis. All costs associated with land purchase, professional consultancy and statutory fees, utility connections, enabling works, civil engineering, landscaping and so forth are excluded from this exercise as beyond its scope: this analysis focuses purely on the construction of the buildings.

Headlines for embodied cost analysis

- Reducing embodied carbon 20-30% attracts a 12-16% uplift in capital cost
- Masonry construction costs least but is the most carbon intensive option, failing to achieve RIBA/ RIAI 2030 and LETI 2030 targets for most typologies
- External finishes can have significant impact on project costs, sales values and embodied carbon - but do not directly impact building performance

Cost analyses for the embodied specifications are summarised in the adjacent tables.

Scenario 1: Masonry is the cheapest approach across the typologies. While this may make it attractive to developers, this approach must be acknowledged as the most carbon intensive, failing to achieve RIBA/ RIAI 2030 and LETI 2030 targets for all but **HT 211**.

Scenario 1: Masonry sets a baseline to assess capital cost associated with reducing embodied carbon. Maintaining a constant performance specification **Scenario 2: Framed** attracts an 7% uplift; **Scenario 3: Timber** 13% and **Scenario 4: Timber Optimised** 15%.

However, much of this additional expense is not generated by the thermal envelope but in parts of the building that contribute little - if anything - to energy use in and performance of the building. Accepting there will be implications for the embodied carbon analysis, standardisation of the roof finish to concrete tiles across the scenarios (rather than clay tile, Spanish and Welsh slate) the CAPEX uplift reduces to 6%, 10% and 6% respectively.

HT 211 to AD L (Wales) 2025				
Construction	Scenario 1: Masonry	Scenario 2: Framed	Scenario 3: Timber	Scenario 4: Timber Opt.
Foundations	£22,750.00	£22,750.00	£75,600.00	£22,750.00
Ground floor	£57,240.00	£49,680.00		£23,760.00
External walls	£148,203.00	£166,263.00	£163,788.00	£166,428.00
Party walls	£29,057.50	£59,100.00	£81,755.00	£81,755.00
Internal walls	£35,190.00	£43,470.00	£51,750.00	£60,030.00
Separating floor	£95,400.00	£97,200.00	£97,200.00	£97,200.00
Roof	£47,736.00	£54,216.00	£69,336.00	£101,736.00
Doors & windows	£19,736.00	£19,736.00	£19,736.00	£19,736.00
FF&F	£98,630.10	£98,630.10	£98,630.10	£98,630.10
M&E	£196,650.00	£196,650.00	£196,650.00	£196,650.00
Preliminaries	£93,824.08	£100,961.89	£106,805.64	£108,584.39
TOTAL	**£844,416.68**	**£908,656.99**	**£961,250.74**	**£977,259.49**
Cost per unit	£93,824.08	£100,961.89	£106,805.64	£108,584.39
Cost per m²	£1,568.09	£1,687.39	£1,785.05	£1,814.78

HT 421 to AD L (Wales) 2025				
Construction	Scenario 1: Masonry	Scenario 2: Framed	Scenario 3: Timber	Scenario 4: Timber Opt.
Foundations	£13,000.00	£13,000.00	£38,500.00	£13,000.00
Ground floor	£29,150.00	£25,300.00		£12,100.00
External walls	£67,298.00	£73,258.00	£74,408.00	£75,648.00
Party walls	£5,752.50	£11,700.00	£16,185.00	£16,185.00
Internal walls	£15,300.00	£22,500.00	£22,500.00	£26,100.00
Intermediate floor	£8,360.00	£9,240.00	£9,240.00	£10,560.00
Roof	£24,200.00	£27,500.00	£35,200.00	£51,700.00
Doors & windows	£10,822.40	£10,822.40	£10,822.40	£10,822.40
FF&F	£37,247.60	£37,247.60	£37,247.60	£37,247.60
M&E	£60,800.00	£60,800.00	£60,800.00	£60,800.00
Preliminaries	£33,991.31	£36,421.00	£38,112.88	£39,270.38
TOTAL	**£305,921.81**	**£327,789.00**	**£343,015.88**	**£353,433.38**
Cost per unit	£152,960.91	£163,894.50	£171,507.94	£132,957.70
Cost per m²	£1,838.47	£1,969.89	£2,061.39	£2,124.00

HT 641 to AD L (Wales) 2025				
Construction	Scenario 1: Masonry	Scenario 2: Framed	Scenario 3: Timber	Scenario 4: Timber Opt.
Foundations	£8,750.00	£8,750.00	£25,550.00	£8,750.00
Ground floor	£19,345.00	£16,790.00		£8,030.00
External walls	£54,230.00	£58,990.00	£59,960.00	£60,960.00
Internal walls	£9,435.00	£13,875.00	£13,875.00	£16,095.00
Intermediate floor	£5,225.00	£5,775.00	£5,775.00	£6,600.00
Roof	£15,958.00	£18,148.00	£23,258.00	£34,208.00
Doors & windows	£7,018.76	£7,018.76	£7,018.76	£7,018.76
FF&F	£22,865.60	£22,865.60	£22,865.60	£22,865.60
M&E	£37,700.00	£37,700.00	£37,700.00	£37,700.00
Preliminaries	£22,565.92	£23,739.05	£24,500.30	£25,278.42
TOTAL	**£203,093.28**	**£213,651.41**	**£220,502.66**	**£227,505.78**
Cost per unit	£203,093.28	£213,651.41	£220,502.66	£227,505.78
Cost per m²	£1,839.61	£1,935.25	£1,997.31	£2,060.74

This reduction is a direct outcome of the increased cost of natural roof finishes with Welsh slate 6.25x the price of concrete tiles (+525% uplift). What material is specified for the finish does not impact the operational performance - it exists outside of the thermal envelope - but the effect on embodied carbon can be significant.

Considering the embodied carbon of the roof finishes in isolation for WLCA stages A-C:

Concrete tiles	41.38 $kgCO_2e/m^2$
Clay tiles	14.12 $kgCO_2e/m^2$
Spanish slate	8.64 $kgCO_2e/m^2$
Welsh slate	2.83 $kgCO_2e/m^2$

While costing 6.25x as much as concrete tiles, Welsh slate is 14.64x less carbon intensive. This could be extended to all external elements - stone cladding instead of brick in the external walls or timber frame windows in place of uPVC - and demonstrates how aesthetic choices can significantly impact project costs and embodied carbon while having no bearing on building performance and operational Net Zero.

High quality, locally sourced materials can be relatively expensive versus alternatives but have benefits for placemaking and can yield potential reductions in embodied carbon. Considered use of such materials often leverages higher sale values for properties with RICS Placemaking and value (2016) identifying 5-50% premium to sales values from successful placemaking.

Locally sourced materials have the added advantage of more transparent and more readily traceable supply chains. Additional scrutiny contributes to reducing social justice issues, ethical transgressions and the environmental degradation associated with material extraction, refinement and transportation.

Within the context of the declared Climate Emergency and the Wellbeing of Future Generations (Wales) Act 2015 it seems proportionate to accept a capital cost uplift to reduce embodied carbon.

Headlines for operational cost analysis

- Less efficient operational scenarios that omit MVHR (and/ or ASHP) can cost more to achieve Net Zero due to larger PV arrays and heating systems
- Building to LETI demonstrates cost parity with AD: L (Wales) 2025 when achieving Net Zero operational carbon
- Energy efficiency is recognised as contributing to desirability, increased and market-resilient property prices

AD L (Wales) 2025 upgrade to LETI (ex. preliminaries)									
Building Element			HT 211		HT 421		HT 641		
Fabric	Double glazing to triple glazing	additional cost	+	£3,374.96	+	£991.76	+	£623.63	
	ASHP reducing in size	cost saving		N/A	-	£8,000.00	-	£6,000.00	
	MVHR addition	additional cost	+	£27,000.00	+	£7,000.00	+	£4,000.00	
	MEV omission	cost saving	-	£5,400.00	-	£1,800.00	-	£1,200.00	
Generation	PV array decreasing in size	cost saving	-	£11,250.00	-	£1,600.00	-	£1,200.00	
TOTAL			**+**	**£13,724.96**	**-**	**£3,408.24**	**-**	**£3,776.37**	
Cost per unit			+	£1,525.00	-	£1,704.12	-	£3,776.37	
Cost per m² of GIA			+	£25.49	-	£20.48	-	£34.21	

Upgrading **AD: L (Wales) 2025** to **LETI** requires changing only the doors, windows, ventilation and heating units.

The cost implications of these adjustments are explored in the table above. Presented as the cost difference changing from **AD: L (Wales) 2025** to **LETI**, this shows total capital cost decreases for achieving the higher operational standard for **HT 421** and **HT 641**. Despite additional cost installing MVHR, savings are derived from reduced ASHP unit sizes and photovoltaic arrays. **HT 211** is slightly more expensive to uplift as the ASHP remains the same size in both scenarios.

While immediate cost uplift is perceived with replacing MEV with MVHR, heat recovery reduces the heating demand and EUI. If targeting operational Net Zero, the capital cost of MVHR is quickly justified by the savings it can leverage from smaller heating systems (ASHPs) and photovoltaic arrays. Operational cost savings would also be available for the life of the building(s).

Remaining variations are within window specifications, levels of airtightness and mitigation of thermal bridges. The first has negligible impact on cost; the others can be delivered without additional cost by appropriate specification, detailing and workforce skills.

Across all scenarios, if ASHPs were substituted with other less efficient heating and hot water systems this would also make it more difficult to achieve Net Zero and require more investment in photovoltaics and other technologies to balance the increased EUI. This would have the added disadvantage of increasing the operational costs for the life of the building(s).

Generally, as the above discussion of MVHR, lower specifications have increased heating demand and EUI. If the aspiration is to deliver operational Net Zero buildings this, as the above, results in additional cost elsewhere as larger heating systems are required to meet higher peak heating loads and larger arrays of photovoltaic panels are needed to balance higher annual energy consumption.

Lower performance specifications also deliver higher operational costs for building occupants in perpetuity, explored for each typology in 3: Cost Analysis.

Furthermore, use of dwellings post-pandemic has changed with many now providing home offices and more flexible energy profiles through the day: in this context, it is critical to reduce EUI.

This commentary and exercise do not consider the additional capital cost savings available to typologies that, due to favourable scale and form factor, significantly exceed targets for heating demand and EUI. Simplistically, levels of insulation for **HT 211** - and therefore the associated cost of the insulation - could half and still meet **LETI** operational targets.

Before declaration of the Climate Emergency, outbreak of the COVID pandemic or the Russian invasion of Ukraine, RICS Insights into energy efficiency and residential values (2019) identified that increased energy efficiency was beginning to positively impact property values. Referred to as the 'green premium,' recent turmoil in the domestic energy market has seen this translate into energy efficient properties being more desirable for purchasers, commanding higher sales values and more successfully retaining value during periods of market instability.

Some specification decisions are driven by logistics rather than capital cost or carbon intensity. For example, concrete decks are typically favoured over suspended timber floors because they establish a level working platform and can withstand longer exposure to wet weather and generally inclement conditions.

Similarly, timber frame is becoming increasingly common for new-build housing due to its efficiency and flexibility versus conventional masonry. An added advantage is the compatibility of timber with Modern Methods of Construction (MMC) and delivery of prefabricated panellised or 3D volumetric units to site to expedite construction programmes.

Section 3: Cost Analysis

3.1 Residential

3.1.1 HT 211

This section contains a summary of the operational and embodied assessment of **HT 211** with high-level costings followed by detailed cost analyses on pages 9-10. For illustrative drawings of the building and its modelled context, please refer to 5: Appendices.

Operational outputs demonstrate the benefits of form factor and the efficiencies of density: space heating demand reduces more than 90% from AD: L (Wales) 2025 to LETI operational scenarios. This results in an almost 40% reduction in EUI and resulting potential CO_2e emissions and the number of photovoltaics required to achieve Net Zero.

As previously discussed, this typology illustrates that applying a standard specification is not the most material efficient way of achieving low energy building standards. Apartments and other buildings with good form factor can use a lower fabric specification and still achieve high performance levels. Reducing the fabric specification - the quantity of insulation - could achieve further reductions to the calculated embodied energy.

Embodied outputs and the colour-coded LETI diagram demonstrate the relative carbon intensities of the modelled construction scenarios. Excluding internal finishes and fittings, all scenarios achieve both the RIBA/ RIAI 2030 and LETI 2030 targets. Twin Stud Cellulose (Scenario 4) delivers the lowest carbon intensity, prioritising short-term rotation and recycled biogenic materials, with 5x more carbon sequestered than the equivalent masonry construction. Detailed embodied information is diagrammed on page 8.

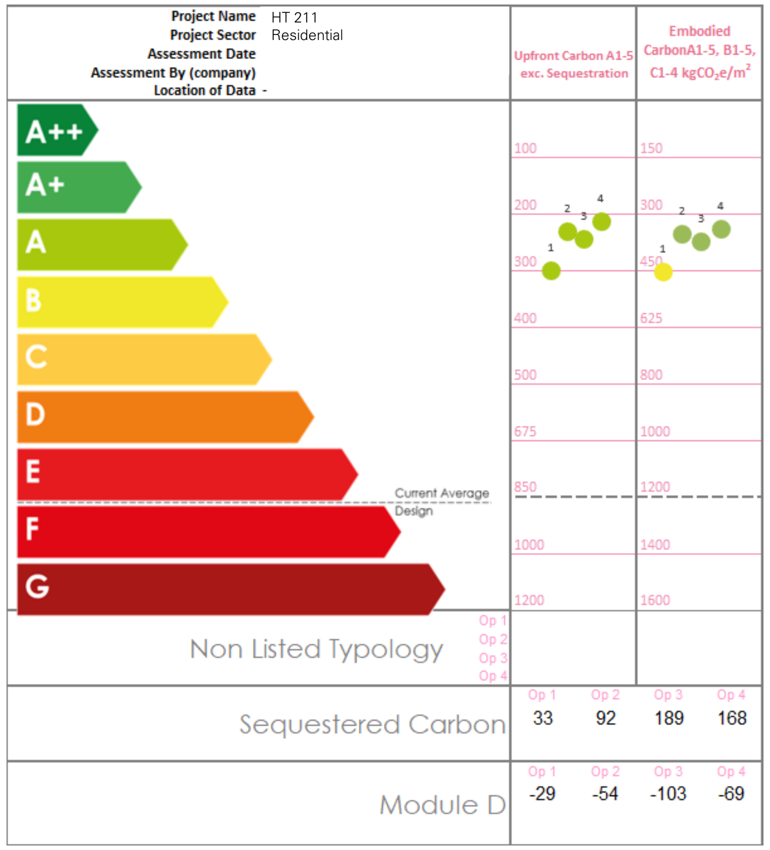
Cost Analysis to LETI presents the breakdown of costs apportioned to various building components for the four scenarios. This shows that masonry - the most carbon intensive scenario - is the cheapest to build with an uplift of 7% associated with changing to timber frame and 10-12% employing timber frame with biogenic insulants when roof coverings are regularised. A large portion of the residual uplift can be assigned to Party and Internal walls which could be value engineered to deliver a more cost-effective solution without increasing embodied carbon. The additional cost masks considerable on-site advantages to building with timber including accelerated build programmes, greater flexibility during construction and the ability to incorporate MMC. Building with timber is actively promoted by Welsh Government.

Operational outputs					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	CO_2e emissions ex. PV (60 yrs)	kWp of PV to Net Zero per dwelling
1 AD: L (Wales) 2025	60.7 kWh/m²/yr	44.9 kWh/m²/yr	2,686 kWh/yr	10.10 tonnes	4.0 kWp
2 AECB CarbonLite	19.7 kWh/m²/yr	37.5 kWh/m²/yr	2,244 kWh/yr	8.53 tonnes	2.9 kWp
3 B&NES	13.4 kWh/m²/yr	33.0 kWh/m²/yr	1,974 kWh/yr	7.49 tonnes	2.5 kWp
4 LETI	3.9 kWh/m²/yr	28.5 kWh/m²/yr	1,705 kWh	6.44 tonnes	2.4 kWp

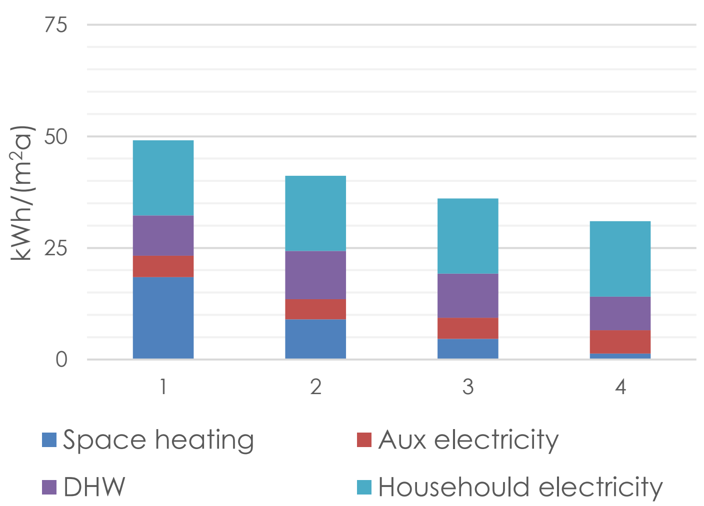
Embodied outputs					
		LETI			
Option	RIBA/ RIAI (cradle to grave)	Upfront carbon A1-5	Embodied carbon A1-5, B1-5, C1-4	Sequestered carbon	Module D (offsite benefits)
1 Masonry	486 $kgCO_2e/m^2$	298 $kgCO_2e/m^2$	457 $kgCO_2e/m^2$	33 $kgCO_2e/m^2$	-29 $kgCO_2e/m^2$
2 Framed	389 $kgCO_2e/m^2$	234 $kgCO_2e/m^2$	359 $kgCO_2e/m^2$	92 $kgCO_2e/m^2$	-54 $kgCO_2e/m^2$
3 Timber	405 $kgCO_2e/m^2$	242 $kgCO_2e/m^2$	376 $kgCO_2e/m^2$	189 $kgCO_2e/m^2$	-103 $kgCO_2e/m^2$
4 Timber Optimised	373 $kgCO_2e/m^2$	212 $kgCO_2e/m^2$	343 $kgCO_2e/m^2$	168 $kgCO_2e/m^2$	-69 $kgCO_2e/m^2$

Cost Analysis to LETI				
Construction	Scenario 1: Masonry	Scenario 2: Framed	Scenario 3: Timber	Scenario 4: Timber Opt.
Foundations	£22,750.00	£22,750.00	£75,600.00	£22,750.00
Ground floor	£57,240.00	£49,680.00		£23,760.00
External walls	£148,203.00	£166,263.00	£163,788.00	£166,428.00
Party walls	£29,057.50	£59,100.00	£81,755.00	£81,755.00
Internal walls	£35,190.00	£43,470.00	£51,750.00	£60,030.00
Separating floor	£95,400.00	£97,200.00	£97,200.00	£97,200.00
Roof	£47,736.00	£54,216.00	£69,336.00	£101,736.00
Doors & windows	£23,110.96	£23,110.96	£23,110.96	£23,110.96
FF&F	£98,630.00	£98,630.00	£98,630.00	£98,630.00
M&E	£207,000.00	£207,000.00	£207,000.00	£207,000.00
Preliminaries	£95,539.70	£102,677.51	£108,521.26	£110,300.01
TOTAL	**£859,857.26**	**£924,097.57**	**£976,691.32**	**£992,700.07**
Cost per unit	£95,539.70	£102,677.51	£108,521.26	£110,300.01
Cost per m²	£1,596.76	£1,716.06	£1,813.73	£1,843.45

LETI embodied carbon reporting - HT 211

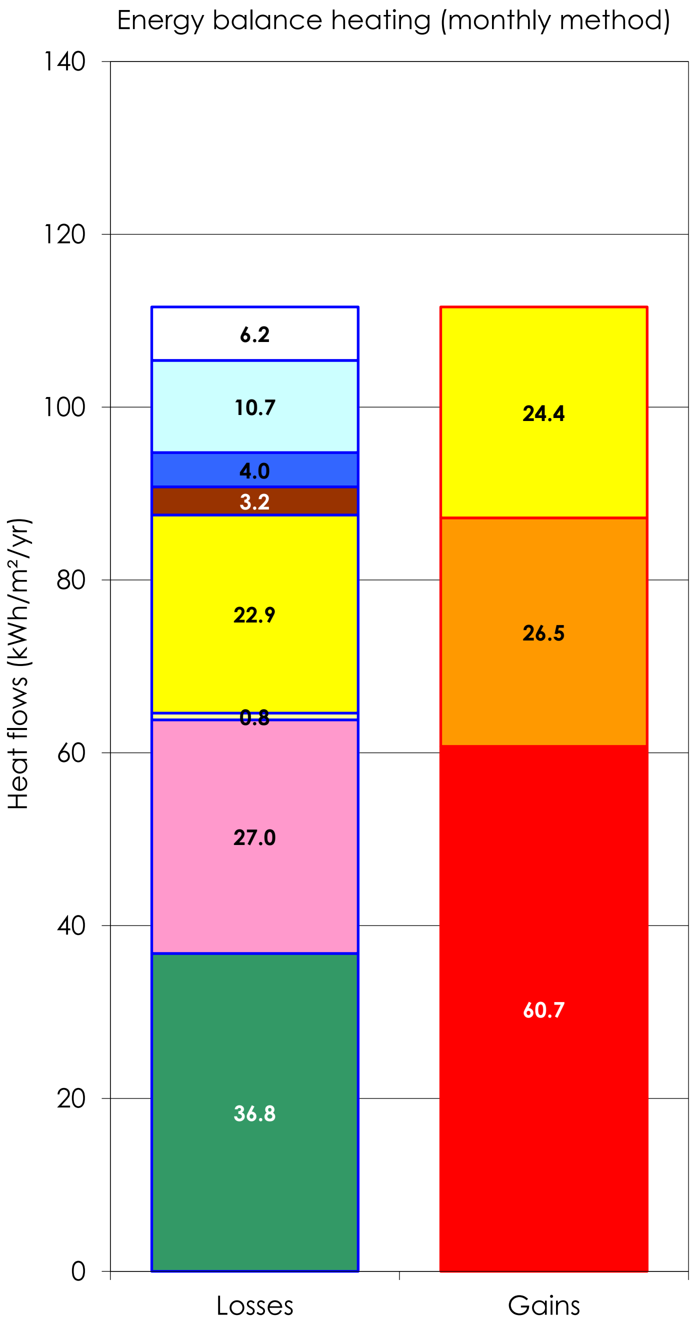


Energy consumption by use - HT 211

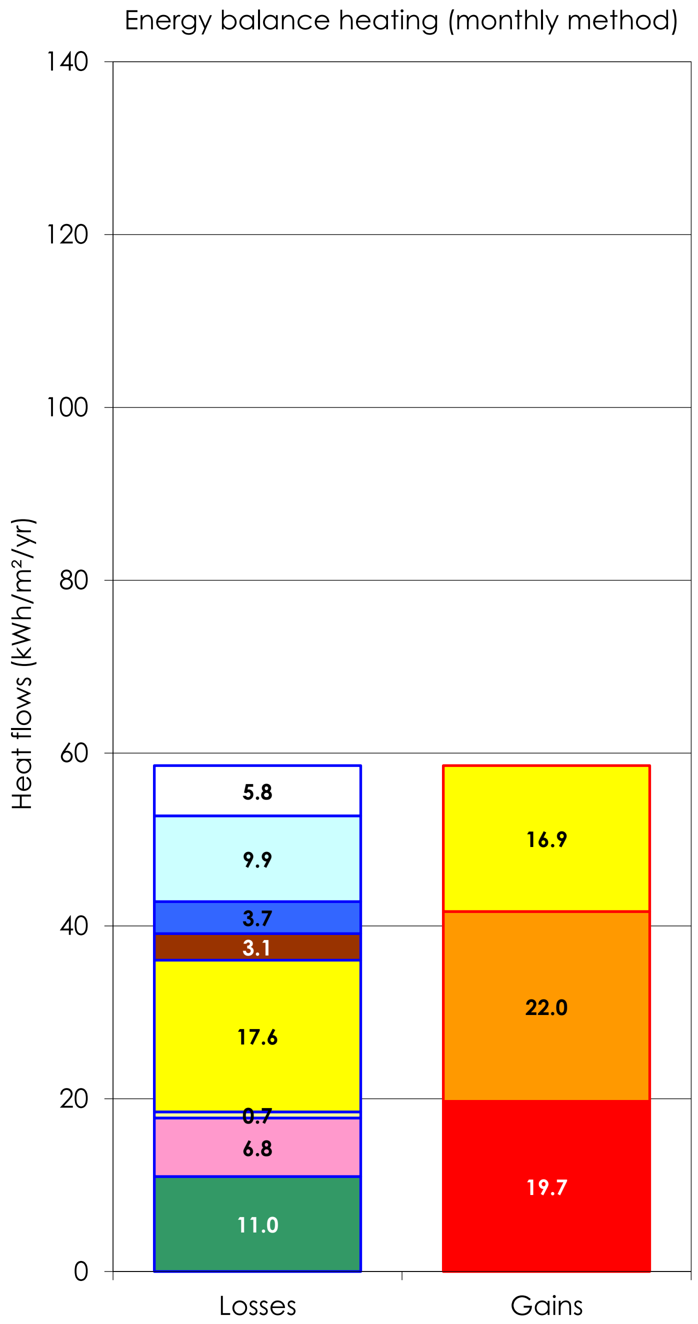


Operational Scenarios

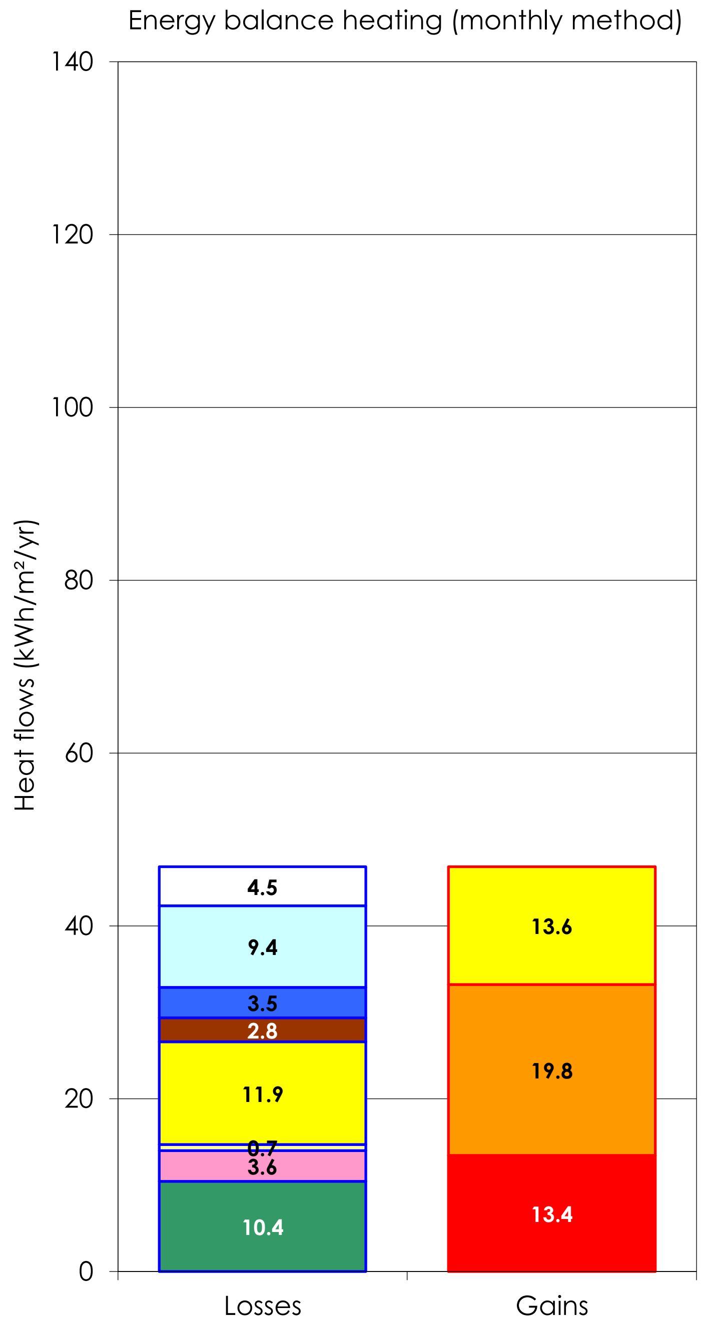
HT 211 - AD: L (Wales) 2025



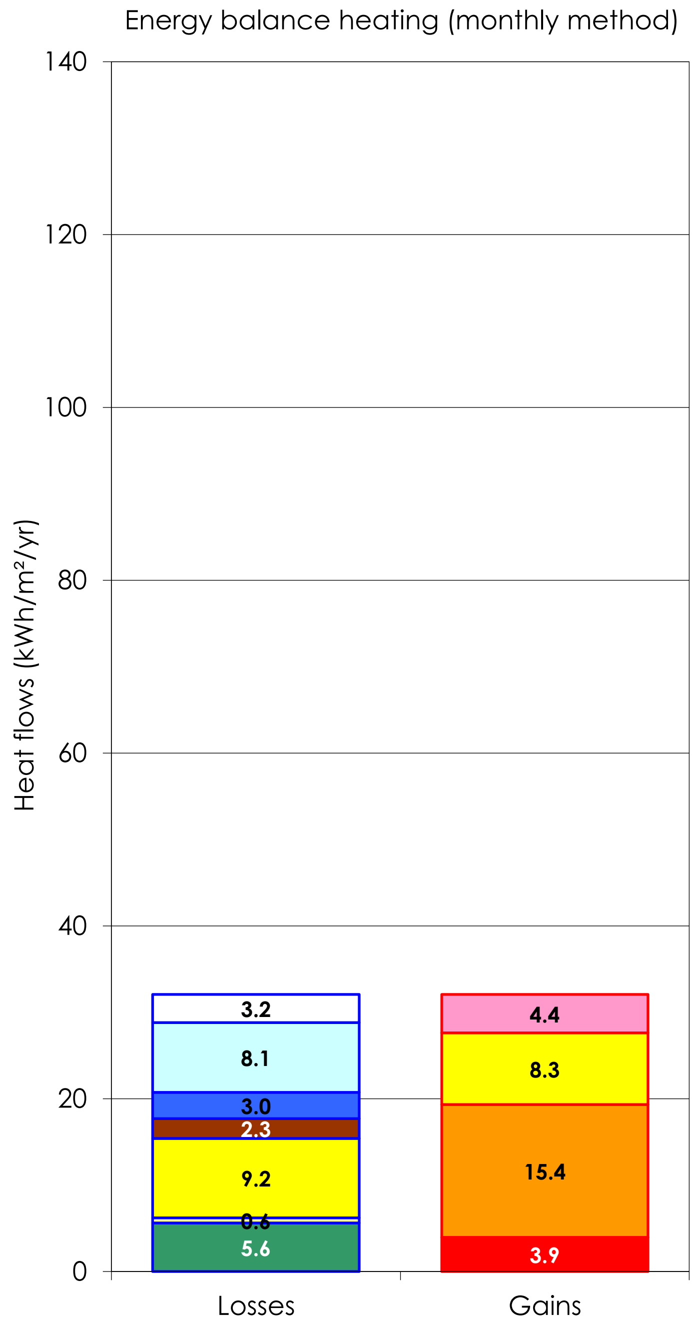
HT 211 - AECB CarbonLite



HT 211 - B&NES



HT 211 - LETI



This page contains the energy balance from PHPP for the four energy scenarios. These graphical outputs illustrate where both heat losses and gains - which must be balanced to maintain a stable, comfortable internal temperature - occur: this information can be used to interrogate the performance of the building fabric and optimise specifications.

Annual energy bills calculated by multiplying EUI by Ofgem Q2 2024 electricity unit rate of £0.245 per kWh

Projected annual electricity bills

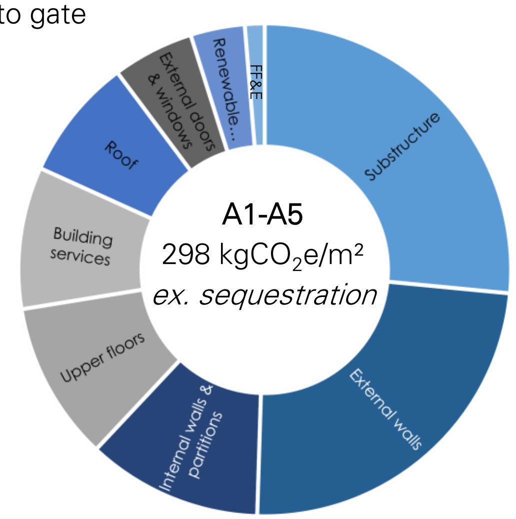
- AD:L (Wales) 2025 £658.07
- AECB CarbonLite £549.78
- B&NES £483.63
- LETI £417.73

excludes standing charge & PV offsets

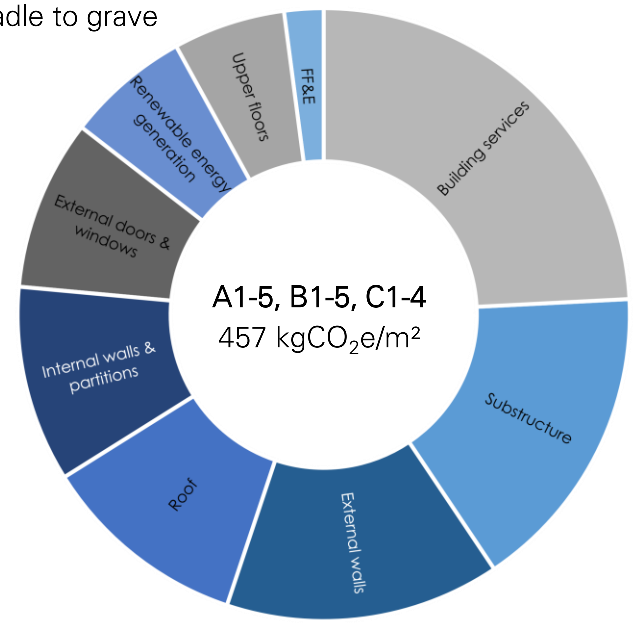
Embodied Scenarios

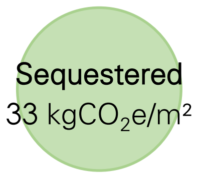
HT 211 - Scenario 1
BUA: Masonry with PIR
diagrams exclude groundworks

Cradle to gate



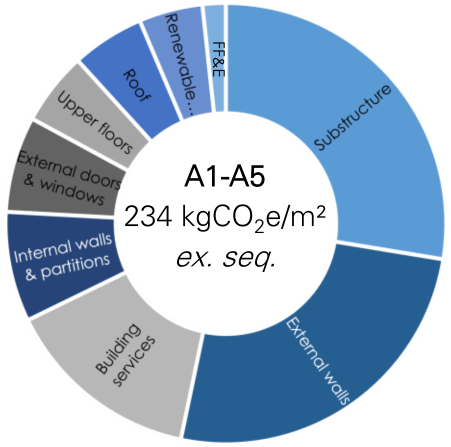
Cradle to grave



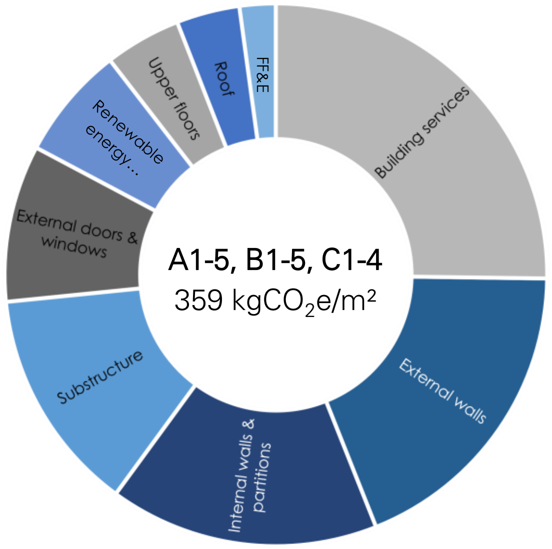


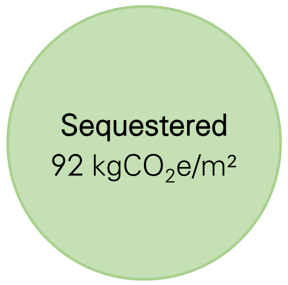
HT 211 - Scenario 2
Framed: 140mm Stud Mineral Wool & PIR
diagrams exclude groundworks

Cradle to gate



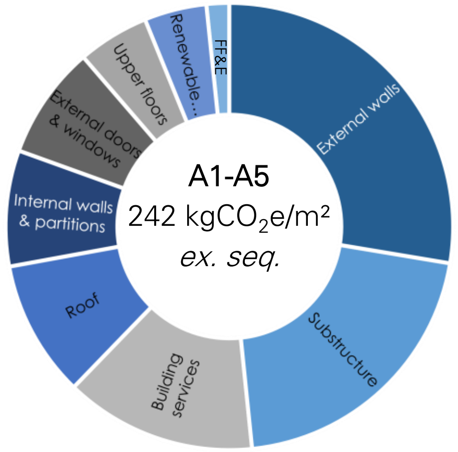
Cradle to grave



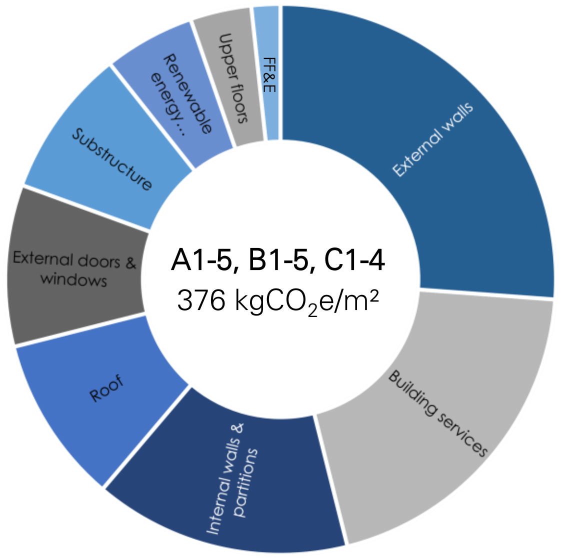


HT 211 - Scenario 3
Timber: 140mm Stud Woodfibre
diagrams exclude groundworks

Cradle to gate

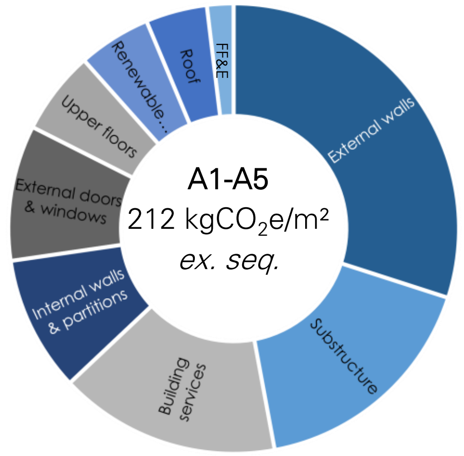


Cradle to grave

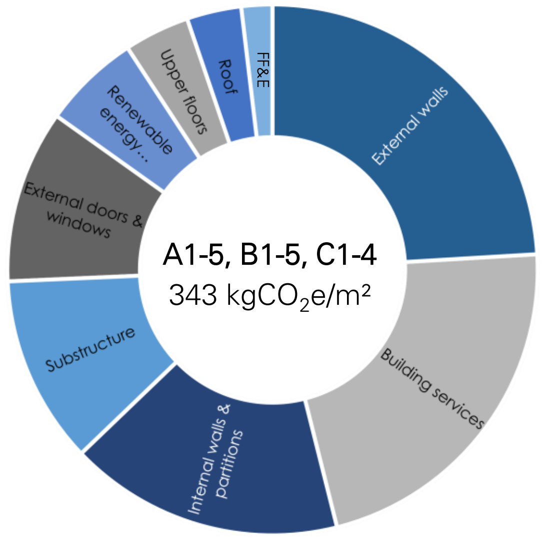


HT 211 - Scenario 4
Timber Optimised: Twin Stud Cellulose
diagrams exclude groundworks

Cradle to gate



Cradle to grave



Construction to AD: L (Wales)	Scenario 1: Masonry		Scenario 2: Framed		Scenario 3: Timber		Scenario 4: Timber Optimised	
Foundations	Concrete trench fill	£22,750.00	Concrete trench fill	£22,750.00			Concrete trench fill	£22,750.00
		£22,750.00		£22,750.00				£22,750.00
Ground floor	Sand & cement screed	£8,640.00	Sand & cement screed	£8,640.00	Reinforced concrete raft	£48,600.00	Chipboard floor finish	£5,400.00
	PIR insulation	£19,440.00	XPS insulation	£19,440.00	Jackon XPS formwork	£27,000.00	STEICOjoist w/ WarmCel	£18,360.00
	Concrete slab	£29,160.00	Beam & block floor	£21,600.00				
		£57,240.00	14% saving	£49,680.00	6% cumulative saving	£75,600.00	59% saving	£23,760.00
External walls	Plasterboard w/ skim	£14,310.00	Plasterboard w/ skim	£14,310.00	Plasterboard w/ skim	£14,310.00	Plasterboard w/ skim	£14,310.00
	Battened service zone	£2,385.00	Battened service zone	£2,385.00	Battened service zone	£2,385.00	Battened service zone	£2,385.00
	Passive Purple VCL	£9,540.00	PIR insulation	£26,350.00	SmartPly ProPassiv OSB	£11,925.00	SmartPly ProPassiv OSB	£11,925.00
	Concrete blockwork	£31,680.00	SmartPly ProPassiv OSB	£11,925.00	Timber stud w/ Gutex	£52,800.00	Twin studs w/ WarmCel	£66,000.00
	PIR insulation	£36,960.00	Timber stud w/ Isover 32	£39,600.00	Gutex Multitherm	£29,040.00	Panelvent sheathing board	£18,480.00
	Ventilated cavity	£528.00	Panelvent sheathing board	£18,480.00	Ventilated cavity	£528.00	Ventilated cavity	£528.00
	Brickwork	£52,800.00	Ventilated cavity	£528.00	Brickwork	£52,800.00	Brickwork	£52,800.00
			Brickwork	£52,800.00				
		£148,203.00	+12% uplift	£166,263.00	+11% uplift	£163,788.00	+12% uplift	£166,428.00
Party walls	Sand & cement plaster	£4,925.00	Plasterboard w/ skim	£8,865.00	Plasterboard w/ skim	£8,865.00	Plasterboard w/ skim	£8,865.00
	Blockwork	£7,880.00	Timber stud w/ Isover 32	£12,805.00	Smartply ProPassiv OSB	£4,925.00	Smartply ProPassiv OSB	£4,925.00
	Rockwool filled cavity	£1,477.00	Smartply ProPassiv OSB	£4,925.00	Timber stud w/ WarmCel	£18,715.00	Timber stud w/ WarmCel	£18,715.00
	Blockwork	£7,880.00	Isover 32 filled cavity	£5,910.00	OSB sheathing	£3,940.00	OSB sheathing	£3,940.00
	Sand & cement plaster	£4,925.00	Smartply ProPassiv OSB	£4,925.00	WarmCel filled cavity	£8,865.00	WarmCel filled cavity	£8,865.00
			Timber stud w/ Isover 32	£12,805.00	OSB sheathing	£3,940.00	OSB sheathing	£3,940.00
			Plasterboard w/ skim	£8,865.00	Timber stud w/ WarmCel	£18,715.00	Timber stud w/ WarmCel	£18,715.00
					Smartply ProPassiv OSB	£4,925.00	Smartply ProPassiv OSB	£4,925.00
					Plasterboard w/ skim	£8,865.00	Plasterboard w/ skim	£8,865.00
		£29,057.50	+103% uplift	£59,100.00	+181% uplift	£81,755.00	+181% uplift	£81,755.00
Internal walls	Sand & cement plaster	£7,245.00	Plasterboard w/ skim	£12,420.00	Plasterboard w/ skim	£12,420.00	Plasterboard w/ skim	£12,420.00
	Blockwork	£20,700.00	Timber stud w/ Isover 32	£18,630.00	Timber stud w/ Gutex	£26,910.00	Timber stud w/ WarmCel	£35,190.00
	Sand & cement plaster	£7,245.00	Plasterboard w/ skim	£12,420.00	Plasterboard w/ skim	£12,420.00	Plasterboard w/ skim	£12,420.00
		£35,190.00	+24% uplift	£43,470.00	+47% uplift	£51,750.00	+71% uplift	£60,030.00
Separating floor	Screed	£14,400.00	Cellecta Screedboard 28	£18,000.00	Cellecta Screedboard 28	£18,000.00	Cellecta Screedboard 28	£18,000.00
	Damp proof membrane	£1,800.00	OSB deck	£10,800.00	OSB deck	£10,800.00	OSB deck	£10,800.00
	Resilient layer	£10,800.00	W. joists w/ mineral wool	£18,000.00	W. joists w/ mineral wool	£18,000.00	W. joists w/ mineral wool	£18,000.00
	Beam & block	£36,000.00	Resilient bars w/ p-board	£28,800.00	Resilient bars w/ p-board	£28,800.00	Resilient bars w/ p-board	£28,800.00
	Sus. ceiling w/ Rockwool	£21,600.00	Sus. ceiling w/ p-board	£21,600.00	Sus. ceiling w/ p-board	£21,600.00	Sus. ceiling w/ p-board	£21,600.00
	Plasterboard w/ skim	£10,800.00						
		£95,400.00	+2% uplift	£97,200.00	+2% uplift	£97,200.00	+2% uplift	£97,200.00
Roof	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00
	Battened service zone	£2,160.00	Battened service zone	£2,160.00	Battened service zone	£2,160.00	Battened service zone	£2,160.00
	Rockwool insulation	£10,800.00	Earthwool insulation	£12.960.00	SmartPly ProPassiv OSB	£5,400.00	SmartPly ProPassiv OSB	£5,400.00
	Timber trusses	£16,200.00	Timber trusses	£16,200.00	Indinature hemp insulation	£16,200.00	WarmCel insulation	£14,040.00
	Ventilated attic	£216.00	Ventilated attic	£216.00	Timber trusses	£16,200.00	Timber trusses	£16,200.00
	Tile battens	£4,320.00	Tile battens	£4,320.00	Ventilated attic	£216.00	Ventilated attic	£216.00
	Concrete tiles	£8,640.00	Clay tiles	£12,960.00	Tile battens	£4,320.00	Tile battens	£4,320.00
					Spanish slate	£19,440.00	Welsh slate	£54,000.00
		£47,736.00	+14% uplift	£54,216.00	+45% uplift	£69,336.00	+113% uplift	£101,736.00
External doors & windows	Windows PAS 24 DG	£16,736.00	Windows PAS 24 DG	£16,736.00	Windows PAS 24 DG	£16,736.00	Windows PAS 24 DG	£16,736.00
	External doors	£3,500.00	External doors	£3,500.00	External doors	£3,500.00	External doors	£3,500.00
		£19,736.00		£19,736.00		£19,736.00		£19,736.00
Finishes, fixtures & fittings	Internal doors	£31,500.00	Internal doors	£31,500.00	Internal doors	£31,500.00	Internal doors	£31,500.00
	Floor finishes	£972.00	Floor finishes	£972.00	Floor finishes	£972.00	Floor finishes	£972.00
	Wall finishes	£17,316.00	Wall finishes	£17,316.00	Wall finishes	£17,316.00	Wall finishes	£17,316.00
	Ceiling finishes	£3,842.10	Ceiling finishes	£3,842.10	Ceiling finishes	£3,842.10	Ceiling finishes	£3,842.10
	Kitchen F&F	£31,500.00	Kitchen F&F	£31,500.00	Kitchen F&F	£31,500.00	Kitchen F&F	£31,500.00
	Shower room F&F	£13,500.00	Shower room F&F	£13,500.00	Shower room F&F	£13,500.00	Shower room F&F	£13,500.00
		£98,630.10		£98,630.10		£98,630.10		£98,630.10
M&E	General electrical circuit	£40,500.00	General electrical circuit	£40,500.00	General electrical circuit	£40,500.00	General electrical circuit	£40,500.00
	ASHPs w/ cylinders	£108,000.00	ASHPs w/ cylinders	£108,000.00	ASHPs w/ cylinders	£108,000.00	ASHPs w/ cylinders	£108,000.00
	MEV units (2 per unit)	£5,400.00	MEV units (2 per unit)	£5,400.00	MEV units (2 per unit)	£5,400.00	MEV units (2 per unit)	£5,400.00
	PV panels (10 per unit)	£42,750.00	PV panels (10 per unit)	£42,750.00	PV panels (10 per unit)	£42,750.00	PV panels (10 per unit)	£42,750.00
		£196,650.00		£196,650.00		£196,650.00		£196,650.00
Preliminaries (12.5%)		£93,824.08		£100,961.89		£106,805.64		£108,584.39
TOTAL		£844,416.68	+8% uplift	£908,656.99	+14% uplift	£961,250.74	+16% uplift	£977,259.49

HT 211 AD: L cost analysis headlines

- 16% capital cost uplift can reduce cradle-to-grave embodied carbon 25% (RIBA/ RIAI and LETI) & upfront carbon emissions c. 30% (LETI)
- Cost uplifts (regularised roof finish):
  - Masonry to Framed: 7%
  - Masonry to Timber: 12%
  - Masonry to Timber Opt.: 10%
- Party walls largest single contributor to uplift in cost for timber construction

Critical components of the structure and thermal envelope highlighted in green are essential to achieving the necessary fabric u-values. Note there is no difference between the fabric (except windows) for the two operational scenarios costed.

Highlighting the thermal elements demonstrates the perceived 16% uplift between Scenarios 1 and 4 is primarily attributable to elements that do not form part of the thermal envelope. Party walls, Internal walls and the roof finish produce the most pronounced cost differences; changing External walls from masonry only adds 11-12% to this particular line item and less than 2% to total construction costs. Due to this flatted typology containing the most separating structures the Party walls and Internal walls cost amplifies the uplift.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue. In this instance this excludes the ASHP and cylinders as both operational scenarios employ a 3.5 kW ASHP.

Construction to LETI	Scenario 1: Masonry		Scenario 2: Framed		Scenario 3: Timber		Scenario 4: Timber Optimised	
Foundations	Concrete trench fill	£22,750.00	Concrete trench fill	£22,750.00			Concrete trench fill	£22,750.00
		£22,750.00		£22,750.00				£22,750.00
Ground floor	Sand & cement screed	£8,640.00	Sand & cement screed	£8,640.00	Reinforced concrete raft	£48,600.00	Chipboard floor finish	£5,400.00
	PIR insulation	£19,440.00	XPS insulation	£19,440.00	Jackon XPS formwork	£27,000.00	STEICOjoist w/ WarmCel	£18,360.00
	Concrete slab	£29,160.00	Beam & block floor	£21,600.00				
		£57,420.00		£49,680.00		£75,600.00		£23,760.00
External walls	Plasterboard w/ skim	£14,310.00	Plasterboard w/ skim	£14,310.00	Plasterboard w/ skim	£14,310.00	Plasterboard w/ skim	£14,310.00
	Battened service zone	£2,385.00	Battened service zone	£2,385.00	Battened service zone	£2,385.00	Battened service zone	£2,385.00
	Passive Purple VCL	£9,540.00	PIR insulation	£26,350.00	SmartPly ProPassiv OSB	£11,925.00	SmartPly ProPassiv OSB	£11,925.00
	Concrete blockwork	£31,680.00	SmartPly ProPassiv OSB	£11,925.00	Timber stud w/ Gutex	£52,800.00	Twin studs w/ WarmCel	£66,000.00
	PIR insulation	£36,960.00	Timber stud w/ Isover 32	£39,600.00	Gutex Multitherm	£29,040.00	Panelvent sheathing board	£18,480.00
	Ventilated cavity	£528.00	Panelvent sheathing board	£18,480.00	Ventilated cavity	£528.00	Ventilated cavity	£528.00
	Brickwork	£52,800.00	Ventilated cavity	£528.00	Brickwork	£52,800.00	Brickwork	£52,800.00
			Brickwork	£52,800.00				
		£148,203.00		£166,263.00		£163,788.00		£166,428.00
Party walls	Sand & cement plaster	£4,925.00	Plasterboard w/ skim	£8,865.00	Plasterboard w/ skim	£8,865.00	Plasterboard w/ skim	£8,865.00
	Blockwork	£7,880.00	Timber stud w/ Isover 32	£12,805.00	Smartply ProPassiv OSB	£4,925.00	Smartply ProPassiv OSB	£4,925.00
	Rockwool filled cavity	£1,477.00	Smartply ProPassiv OSB	£4,925.00	Timber stud w/ WarmCel	£18,715.00	Timber stud w/ WarmCel	£18,715.00
	Blockwork	£7,880.00	Isover 32 filled cavity	£5,910.00	OSB sheathing	£3,940.00	OSB sheathing	£3,940.00
	Sand & cement plaster	£4,925.00	Smartply ProPassiv OSB	£4,925.00	WarmCel filled cavity	£8,865.00	WarmCel filled cavity	£8,865.00
			Timber stud w/ Isover 32	£12,805.00	OSB sheathing	£3,940.00	OSB sheathing	£3,940.00
			Plasterboard w/ skim	£8,865.00	Timber stud w/ WarmCel	£18,715.00	Timber stud w/ WarmCel	£18,715.00
					Smartply ProPassiv OSB	£4,925.00	Smartply ProPassiv OSB	£4,925.00
					Plasterboard w/ skim	£8,865.00	Plasterboard w/ skim	£8,865.00
		£29,057.50		£59,100.00		£81,755.00		£81,755.00
Internal walls	Sand & cement plaster	£7,245.00	Plasterboard w/ skim	£12,420.00	Plasterboard w/ skim	£12,420.00	Plasterboard w/ skim	£12,420.00
	Blockwork	£20,700.00	Timber stud w/ Isover 32	£18,630.00	Timber stud w/ Gutex	£26,910.00	Timber stud w/ WarmCel	£35,190.00
	Sand & cement plaster	£7,245.00	Plasterboard w/ skim	£12,420.00	Plasterboard w/ skim	£12,420.00	Plasterboard w/ skim	£12,420.00
		£35,190.00		£43,470.00		£51,750.00		£60,030.00
Intermediate floor	N/A		N/A		N/A		N/A	
Separating floor	Screed	£14,400.00	Cellecta Screedboard 28	£18,000.00	Cellecta Screedboard 28	£18,000.00	Cellecta Screedboard 28	£18,000.00
	Damp proof membrane	£1,800.00	OSB deck	£10,800.00	OSB deck	£10,800.00	OSB deck	£10,800.00
	Resilient layer	£10,800.00	W. joists w/ mineral wool	£18,000.00	W. joists w/ mineral wool	£18,000.00	W. joists w/ mineral wool	£18,000.00
	Beam & block	£36,000.00	Resilient bars w/ p-board	£28,800.00	Resilient bars w/ p-board	£28,800.00	Resilient bars w/ p-board	£28,800.00
	Sus. ceiling w/ Rockwool	£21,600.00	Sus. ceiling w/ p-board	£21,600.00	Sus. ceiling w/ p-board	£21,600.00	Sus. ceiling w/ p-board	£21,600.00
	Plasterboard w/ skim	£10,800.00						
		£95,400.00		£97,200.00		£97,200.00		£97,200.00
Roof	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00
	Battened service zone	£2,160.00	Battened service zone	£2,160.00	Battened service zone	£2,160.00	Battened service zone	£2,160.00
	Rockwool insulation	£10,800.00	Earthwool insulation	£12.960.00	SmartPly ProPassiv OSB	£5,400.00	SmartPly ProPassiv OSB	£5,400.00
	Timber trusses	£16,200.00	Timber trusses	£16,200.00	Indinature hemp insulation	£16,200.00	WarmCel insulation	£14,040.00
	Ventilated attic	£216.00	Ventilated attic	£216.00	Timber trusses	£16,200.00	Timber trusses	£16,200.00
	Tile battens	£4,320.00	Tile battens	£4,320.00	Ventilated attic	£216.00	Ventilated attic	£216.00
	Concrete tiles	£8,640.00	Clay tiles	£12,960.00	Tile battens	£4,320.00	Tile battens	£4,320.00
					Spanish slate	£19,440.00	Welsh slate	£54,000.00
		£47,736.00		£54,216.00		£69,336.00		£101,736.00
External doors & windows	Rehau Artevo TG	£19,610.96	Rehau Artevo TG	£19,610.96	Rehau Artevo TG	£19,610.96	Rehau Artevo TG	£19,610.96
	External doors	£3,500.00	External doors	£3,500.00	External doors	£3,500.00	External doors	£3,500.00
	+17% uplift vs. AD L	£23,110.96	+17% uplift vs. AD L	£23,110.96	+17% uplift vs. AD L	£23,110.96	+17% uplift vs. AD L	£23,110.96
Finishes, fixtures & fittings	Internal doors	£31,500.00	Internal doors	£31,500.00	Internal doors	£31,500.00	Internal doors	£31,500.00
	Floor finishes	£972.00	Floor finishes	£972.00	Floor finishes	£972.00	Floor finishes	£972.00
	Wall finishes	£17,316.00	Wall finishes	£17,316.00	Wall finishes	£17,316.00	Wall finishes	£17,316.00
	Ceiling finishes	£3,842.10	Ceiling finishes	£3,842.10	Ceiling finishes	£3,842.10	Ceiling finishes	£3,842.10
	Kitchen F&F	£31,500.00	Kitchen F&F	£31,500.00	Kitchen F&F	£31,500.00	Kitchen F&F	£31,500.00
	Shower room F&F	£13,500.00	Shower room F&F	£13,500.00	Shower room F&F	£13,500.00	Shower room F&F	£13,500.00
		£98,630.10		£98,630.10		£98,630.10		£98,630.10
M&E	General electrical circuit	£40,500.00	General electrical circuit	£40,500.00	General electrical circuit	£40,500.00	General electrical circuit	£40,500.00
	ASHPs w/ cylinders	£108,000.00	ASHPs w/ cylinders	£108,000.00	ASHPs w/ cylinders	£108,000.00	ASHPs w/ cylinders	£108,000.00
	Zehnder MVHR units	£27,000.00	Zehnder MVHR units	£27,000.00	Zehnder MVHR units	£27,000.00	Zehnder MVHR units	£27,000.00
	PV panels (5 per unit)	£31,500.00	PV panels (5 per unit)	£31,500.00	PV panels (5 per unit)	£31,500.00	PV panels (5 per unit)	£31,500.00
	+7% uplift vs. AD L	£207,000.00	+7% uplift vs. AD L	£207,000.00	+7% uplift vs. AD L	£207,000.00	+7% uplift vs. AD L	£207,000.00
Preliminaries (12.5%)		£95,539.70		£102,677.51		£108,521.26		£110,300.01
TOTAL	+2% uplift vs. AD L	£859,857.26	+2% uplift vs. AD L	£924,097.57	+2% uplift vs. AD L	£976,691.32	+2% uplift vs. AD L	£992,700.07

HT 211 LETI cost analysis headlines

- Window cost difference negligible
- MVHR adds majority of capital uplift but also responsible for improving the operational performance, reducing heating demand and EUI
- 3.5 kW ASHP for both scenarios
- Lower EUI requires only half the PV provision to achieve Net Zero
- Capital cost uplift limited to c. 2%
- Operational cost savings of c. 40%

Critical components of the structure and thermal envelope highlighted in green are essential to achieving the necessary fabric u-values. As previous commentary there is no difference between the fabric (except windows) for the two operational scenarios.

Windows have been upgraded from double to triple glazing for this scenario, costing an extra c. £3,375.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue. In this instance this does not include the ASHP and cylinders as both operational scenarios employ a 3.5 kW ASHP.

While installing MVHR presents a capital cost uplift versus MEV it contributes to reducing space heating demand and EUI. Associated additional costs must be considered against the cost savings realised with these operational improvements: photovoltaic arrays halving in size and greatly reduced operational costs.

Overall there is only a c. 2% capital cost uplift to upgrade AD: L (Wales) 2025 to the LETI operational scenario while running costs would decrease c. 40%.

3.1.2 HT 421

This section contains a summary of the operational and embodied assessment of **HT 421** with high-level costings followed by detailed cost analyses on pages 14-15. For illustrative drawings of the building and its modelled context, please refer to 5: Appendices.

Operational outputs demonstrate the potential to reduce space heating demand more than 80% by improving from AD: L (Wales) 2025 to LETI operational scenarios. This results in a 35% reduction in EUI, potential CO_2e emissions and the number of photovoltaics required to achieve Net Zero.

Embodied outputs and the colour-coded LETI diagram demonstrate the relative carbon intensities of the modelled construction scenarios. Excluding internal finishes and fittings, all timber scenarios achieve both the RIBA/ RIAI 2030 and LETI 2030 targets: Masonry with PIR (Scenario 1) meets the RIBA/ RIAI 2030 target of 625 kgCO_2e/m² but exceeds the LETI 2030 upfront target by more than 25%.

Twin Stud Cellulose (Scenario 4) delivers the lowest carbon intensity, prioritising short-term rotation and recycled biogenic materials, reducing upfront carbon 10% more than other timber options and 30% more than masonry with 2.7x more carbon sequestered. For this typology the sequestered carbon of Twin Stud Cellulose exceeds the upfront carbon emissions.

Cost Analysis to LETI presents the breakdown of costs apportioned to various building components for the four scenarios. This shows that masonry - the most carbon intensive scenario - is the cheapest to build with an uplift of 5% associated with changing to timber frame and 8-10% employing timber frame with biogenic insulants when roof coverings are regularised. A large portion of the residual uplift can be assigned to the Party and Internal walls which could be value engineered to deliver a more cost-effective solution.

Operational outputs - HT 421

Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	CO_2e emissions ex. PV (60 yrs)	kWp of PV to Net Zero per dwelling
1 AD: L (Wales) 2025	87.1 kWh/m²/yr	62.5 kWh/m²/yr	5,200 kWh	19.75 tonnes	7.6 kWp
2 AECB CarbonLite	36.7 kWh/m²/yr	43.8 kWh/m²/yr	3.644 kWh	13.95 tonnes	5.4 kWp
3 B&NES	28.3 kWh/m²/yr	41.8 kWh/m²/yr	3,478 kWh	13.30 tonnes	5.0 kWp
4 LETI	14.3 kWh/m²/yr	40.0 kWh/m²/yr	3,328 kWh	12.75 tonnes	4.8 kWp

Embodied outputs - HT 421

Option	RIBA/ RIAI (cradle to grave)	LETI			
		Upfront carbon A1-5	Embodied carbon A1-5, B1-5, C1-4	Sequestered carbon	Module D (offsite benefits)
1 Masonry	602 kgCO_2e/m²	378 kgCO_2e/m²	531 kgCO_2e/m²	99 kgCO_2e/m²	-67 kgCO_2e/m²
2 Framed	460 kgCO_2e/m²	300 kgCO_2e/m²	390 kgCO_2e/m²	184 kgCO_2e/m²	-104 kgCO_2e/m²
3 Timber	480 kgCO_2e/m²	314 kgCO_2e/m²	410 kgCO_2e/m²	286 kgCO_2e/m²	-166 kgCO_2e/m²
4 Timber Optimised	429 kgCO_2e/m²	266 kgCO_2e/m²	359 kgCO_2e/m²	267 kgCO_2e/m²	-118 kgCO_2e/m²

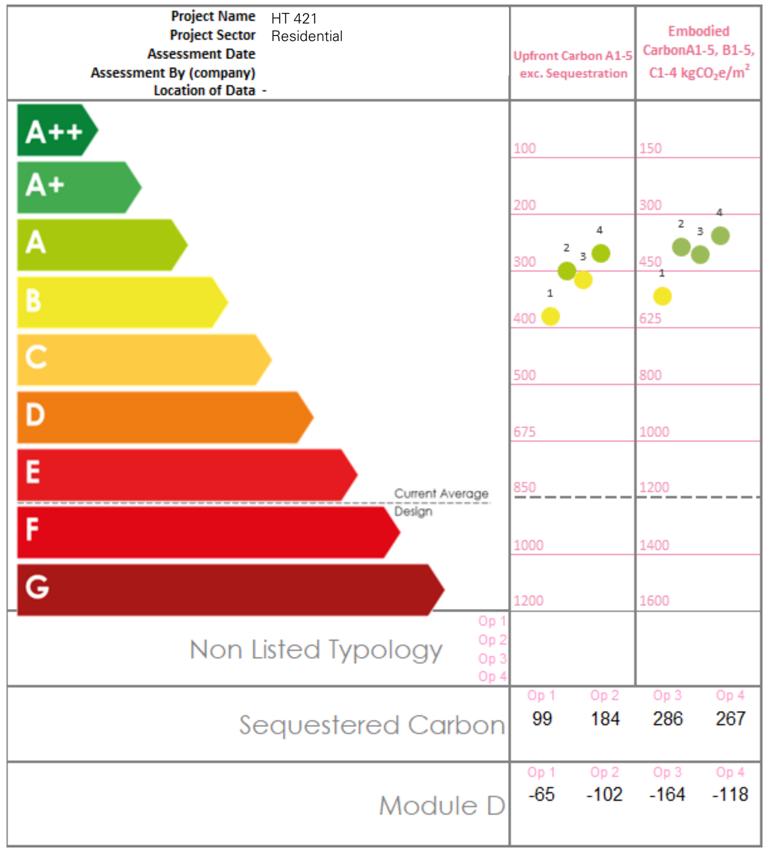
Cost Analysis to LETI

Construction	Scenario 1: Masonry	Scenario 2: Framed	Scenario 3: Timber	Scenario 4: Timber Opt.
Foundations	£13,000.00	£13,000.00	£38,500.00	£13,000.00
Ground floor	£29,150.00	£25,300.00		£12,100.00
External walls	£67,298.00	£73,258.00	£74,408.00	£75,648.00
Party walls	£5,752.50	£11,700.00	£16,185.00	£16,185.00
Internal walls	£15,300.00	£22,500.00	£22,500.00	£26,100.00
Intermediate floor	£8,360.00	£9,240.00	£9,240.00	£10,560.00
Roof	£24,200.00	£27,500.00	£35,200.00	£51,700.00
Doors & windows	£11,814.16	£11,814.16	£11,814.16	£11,814.16
FF&F	£37,247.60	£37,247.60	£37,247.60	£37,247.60
M&E	£56,400.00	£56,400.00	£56,400.00	£56,400.00
Preliminaries	£33,565.28	£35,994.97	£37,686.85	£38,844.35
TOTAL	**£302,087.54**	**£323,954.73**	**£339,181.61**	**£349,599.11**
Cost per unit	£151,043.77	£161,977.37	£169,590.80	£174,799.55
Cost per m²	£1,815.43	£1,946.84	£2,038.35	£2,100.96

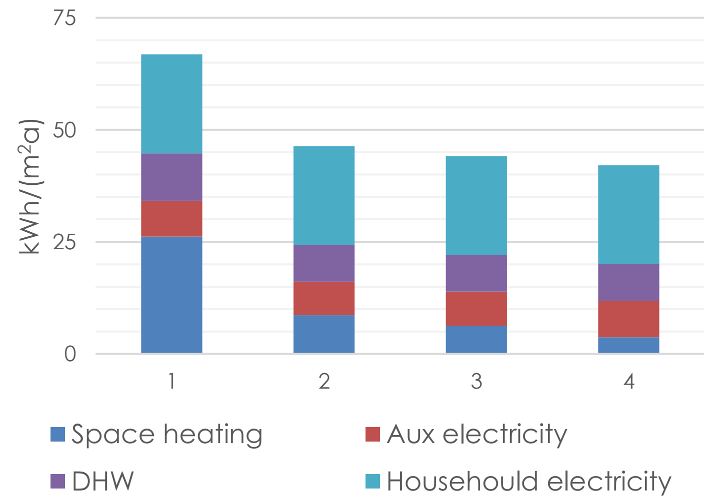
The additional cost masks considerable advantages to building with timber on-site including accelerated build programmes, greater flexibility during construction and the ability to incorporate MMC.

The use of timber in construction is actively promoted by Welsh Government.

LETI embodied carbon reporting - HT 421



Energy consumption by use - HT 421



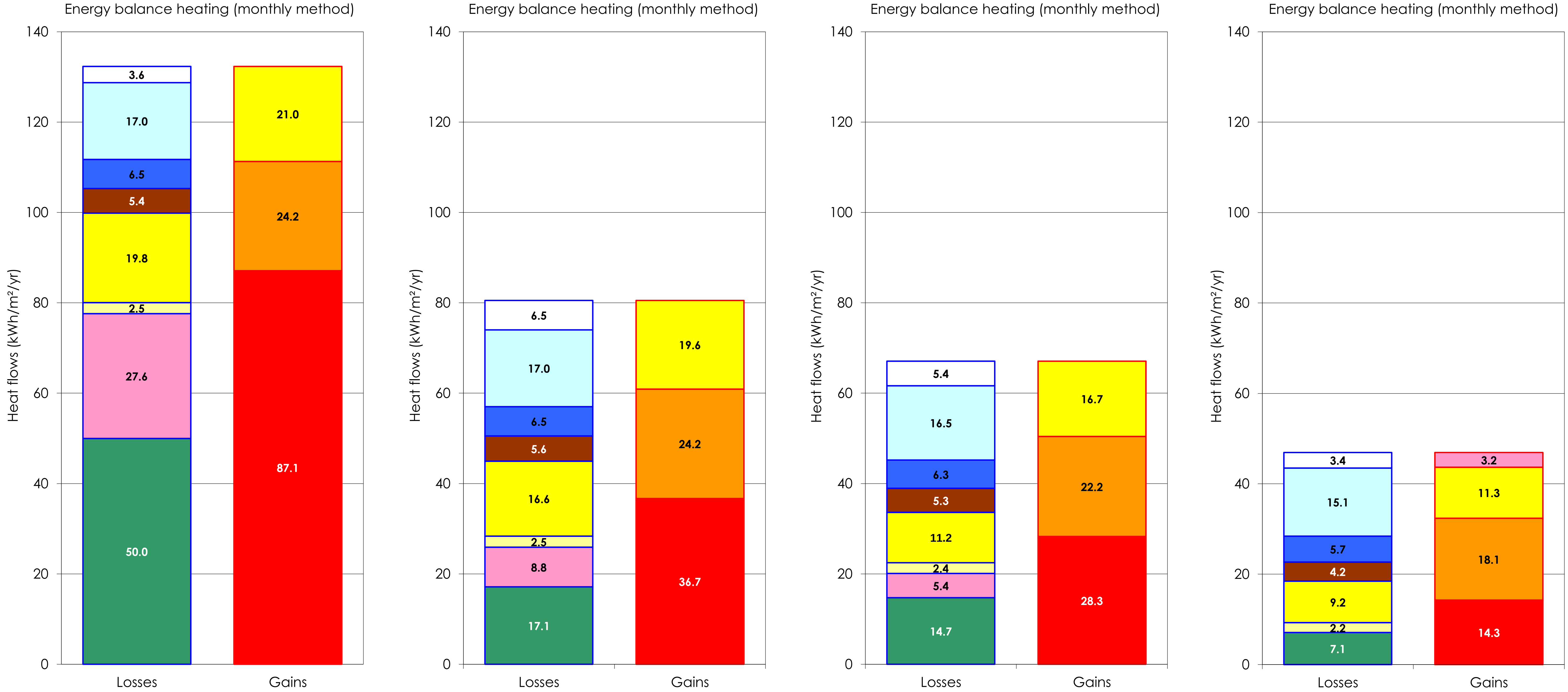
Operational Scenarios

HT 421 - AD: L (Wales) 2025

HT 421 - AECB CarbonLite

HT 421 - B&NES

HT 421 - LETI



- Non-useful gains
- External walls
- Roof/ ceiling
- Floor slab
- Windows
- External door
- Thermal bridges
- Ventilation
- Thermal bridges
- Solar gains
- Internal gains
- Heating demand

This page contains the energy balance from PHPP for the four energy scenarios. These graphical outputs illustrate where both heat losses and gains - which must be balanced to maintain a stable, comfortable internal temperature - occur: this information can be used to interrogate the performance of the building fabric and optimise specifications.

Annual energy bills calculated by multiplying EUI by Ofgem Q2 2024 electricity unit rate of £0.245 per kWh

Projected annual electricity bills

- AD:L (Wales) 2025 £1,274.00
- AECB CarbonLite £892.78
- B&NES £852.11
- LETI £815.36

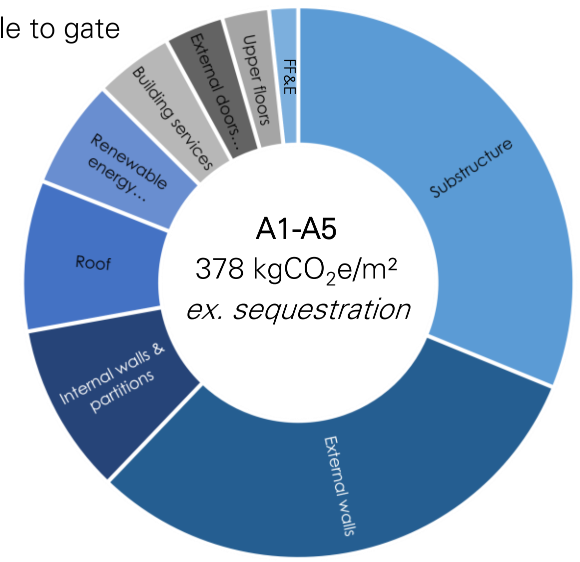
excludes standing charge & PV offsets

spring design

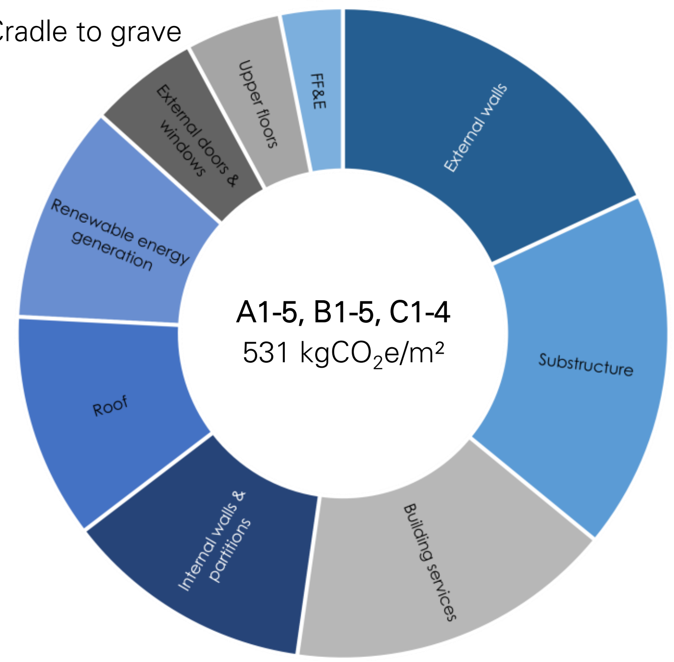
Embodied Scenarios

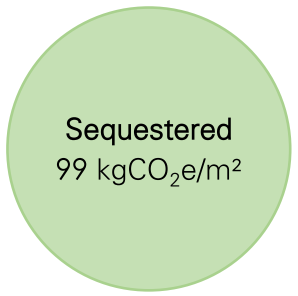
HT 421 - Scenario 1
BUA: Masonry with PIR
diagrams exclude groundworks

Cradle to gate



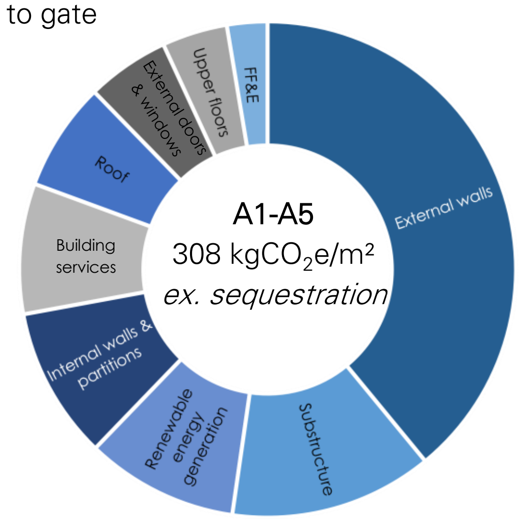
Cradle to grave



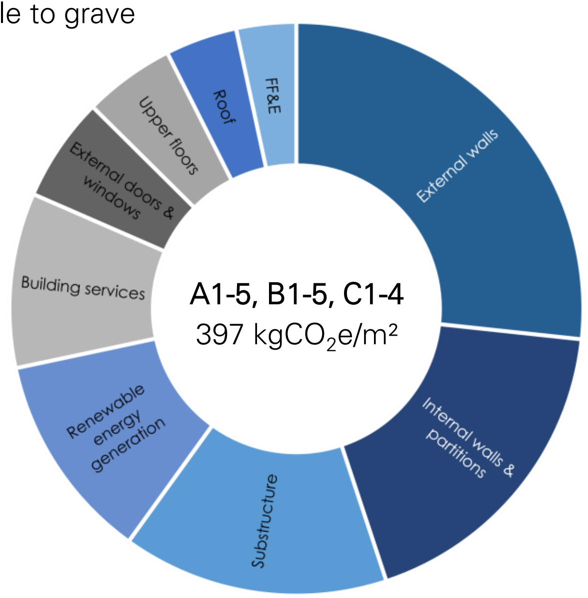


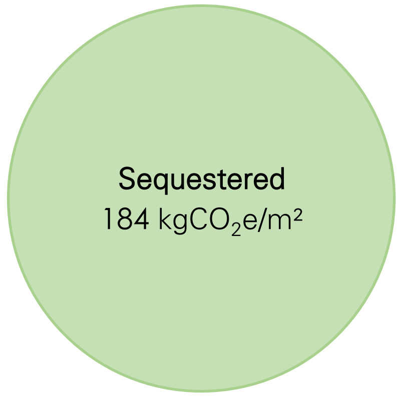
HT 421 - Scenario 2
Framed: 140mm Stud Mineral Wool & PIR
diagrams exclude groundworks

Cradle to gate



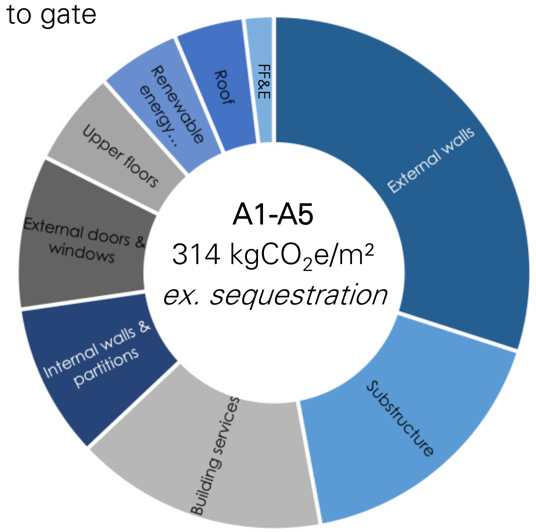
Cradle to grave



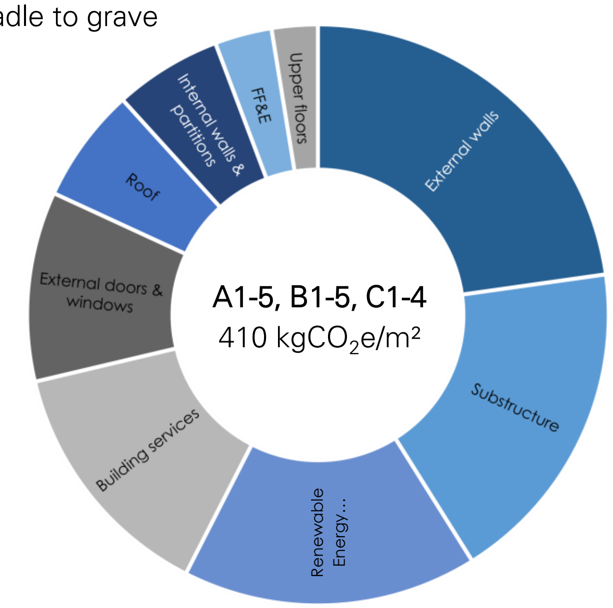


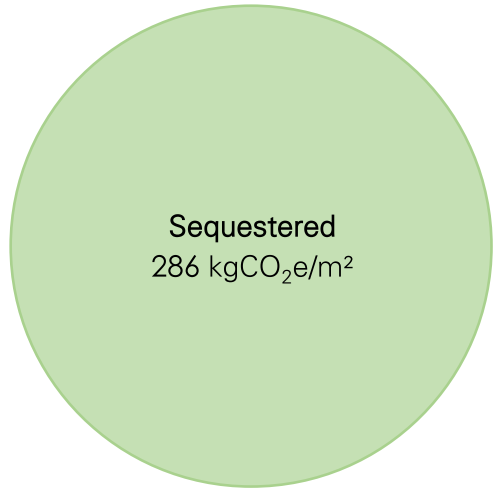
HT 421 - Scenario 3
Timber: 140mm Stud Woodfibre
diagrams exclude groundworks

Cradle to gate



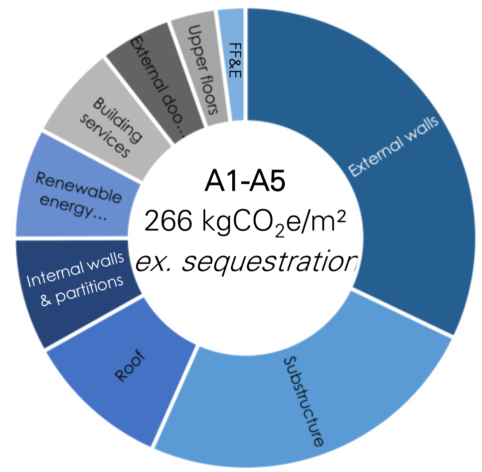
Cradle to grave



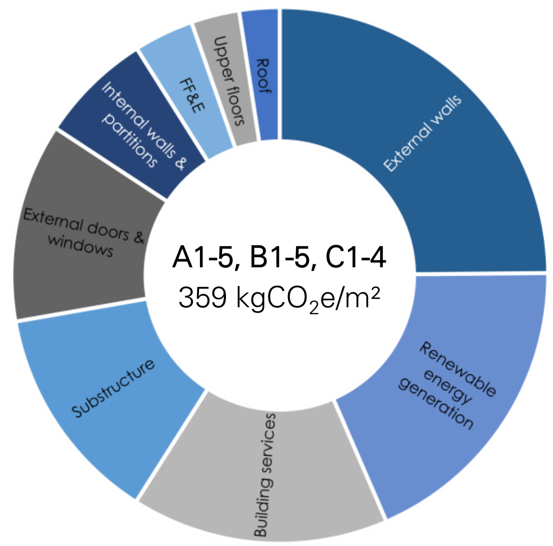


HT 421 - Scenario 4
Timber Optimised: Twin Stud Cellulose
diagrams exclude groundworks

Cradle to gate



Cradle to grave



spring design

Construction to AD: L (Wales)	Scenario 1: Masonry		Scenario 2: Framed		Scenario 3: Timber		Scenario 4: Timber Optimised	
Foundations	Concrete trench fill	£13,000.00	Concrete trench fill	£13,000.00			Concrete trench fill	£13,000.00
		£13,000.00		£13,000.00				£13,000.00
Ground floor	Sand & cement screed	£4,400.00	Sand & cement screed	£4,400.00	Reinforced concrete raft	£24,750.00	Chipboard floor finish	£2,750.00
	PIR insulation	£9,900.00	XPS insulation	£9,900.00	Jackon XPS formwork	£13,750.00	STEICOjoist w/ WarmCel	£9,350.00
	Concrete slab	£14,850.00	Beam & block floor	£11,000.00				
		£29,150.00	13% saving	£25,300.00	9% cumulative saving	£38,500.00	58% saving	£12,100.00
External walls	Plasterboard w/ skim	£5,460.00	Plasterboard w/ skim	£5,460.00	Plasterboard w/ skim	£5,460.00	Plasterboard w/ skim	£5,460.00
	Battened service zone	£910.00	Battened service zone	£910.00	Battened service zone	£910.00	Battened service zone	£910.00
	Passive Purple VCL	£3,640.00	PIR insulation	£10,010.00	SmartPly ProPassiv OSB	£4,550.00	SmartPly ProPassiv OSB	£4,550.00
	Concrete blockwork	£14,880.00	SmartPly ProPassiv OSB	£4,550.00	Timber stud w/ Gutex	£24,800.00	Twin studs w/ WarmCel	£31,000.00
	PIR insulation	£17,360.00	Timber stud w/ Isover 32	£18,600.00	Gutex Multitherm	£13,640.00	Panelvent sheathing board	£8,680.00
	Ventilated cavity	£248.00	Panelvent sheathing board	£8,680.00	Ventilated cavity	£248.00	Ventilated cavity	£428.00
	Brickwork	£24,800.00	Ventilated cavity	£248.00	Brickwork	£24,800.00	Brickwork	£24,800.00
			Brickwork	£24,800.00				
		£67,298.00	+9% uplift	£73,258.00	+11% uplift	£74,408.00	+12% uplift	£75,648.00
Party walls	Sand & cement plaster	£975.00	Plasterboard w/ skim	£1,755.00	Plasterboard w/ skim	£1,755.00	Plasterboard w/ skim	£1,755.00
	Blockwork	£1,560.00	Timber stud w/ Isover 32	£2,535.00	Smartply ProPassiv OSB	£975.00	Smartply ProPassiv OSB	£975.00
	Rockwool filled cavity	£292.50	Smartply ProPassiv OSB	£975.00	Timber stud w/ WarmCel	£3,705.00	Timber stud w/ WarmCel	£3,705.00
	Blockwork	£1,950.00	Isover 32 filled cavity	£1,170.00	OSB sheathing	£780.00	OSB sheathing	£780.00
	Sand & cement plaster	£975.00	Smartply ProPassiv OSB	£975.00	WarmCel filled cavity	£1,755.00	WarmCel filled cavity	£1,755.00
			Timber stud w/ Isover 32	£2,535.00	OSB sheathing	£780.00	OSB sheathing	£780.00
			Plasterboard w/ skim	£1,755.00	Timber stud w/ WarmCel	£3,705.00	Timber stud w/ WarmCel	£3,705.00
					Smartply ProPassiv OSB	£975.00	Smartply ProPassiv OSB	£975.00
					Plasterboard w/ skim	£1,755.00	Plasterboard w/ skim	£1,755.00
		£5,752.50	+103% uplift	£11,700.00	+181% uplift	£16,185.00	+181% uplift	£16,185.00
Internal walls	Sand & cement plaster	£3,150.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00
	Blockwork	£9,000.00	Timber stud w/ Isover 32	£11,700.00	Timber stud w/ Gutex	£11,700.00	Timber stud w/ WarmCel	£15,300.00
	Sand & cement plaster	£3,150.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£15,400.00
		£15,300.00	+47% uplift	£22,500.00	+47% uplift	£22,500.00	+71% uplift	£26,100.00
Intermediate floor	Chipboard floor finish	£2,200.00	Chipboard floor finish	£2,200.00	Chipboard floor finish	£2,200.00	Chipboard floor finish	£2,200.00
	W. joists w/ Rockwool	£3,520.00	W. joists w/ Earthwool	£4,400.00	W. joists w/ Gutex	£4,400.00	W. joists w/ WarmCel	£5,720.00
	Plasterboard with skim	£2,640.00	Plasterboard with skim	£2,640.00	Plasterboard with skim	£2,640.00	Plasterboard with skim	£2,640.00
		£8,360.00	+11% uplift	£9,240.00	+11% uplift	£9,240.00	+26% uplift	£10,560.00
Roof	Plasterboard w/ skim	£2,640.00	Plasterboard w/ skim	£2,640.00	Plasterboard w/ skim	£2,640.00	Plasterboard w/ skim	£2,640.00
	Battened service zone	£1,100.00	Battened service zone	£1,100.00	Battened service zone	£1,100.00	Battened service zone	£1,100.00
	Rockwool insulation	£5,500.00	Earthwool insulation	£6,600.00	SmartPly ProPassiv OSB	£2,750.00	SmartPly ProPassiv OSB	£2,750.00
	Timber trusses	£8,250.00	Timber trusses	£8,250.00	Indinature hemp insulation	£8,250.00	WarmCel insulation	£7,150.00
	Ventilated attic	£110.00	Ventilated attic	£110.00	Timber trusses	£8,250.00	Timber trusses	£8,250.00
	Tile battens	£2,200.00	Tile battens	£2,200.00	Ventilated attic	£110.00	Ventilated attic	£110.00
	Concrete tiles	£4,400.00	Clay tiles	£6,600.00	Tile battens	£2,200.00	Tile battens	£2,200.00
					Spanish slate	£9,900.00	Welsh slate	£27,500.00
		£24,200.00	+14% uplift	£27,500.00	+45% uplift	£35,200.00	+114% uplift	£51,700.00
External doors & windows	Rehau Artevo TG	£10,822.40	Rehau Artevo TG	£10,822.40	Rehau Artevo TG	£10,822.40	Rehau Artevo TG	£10,822.40
	External doors	*included above*	External doors	*included above*	External doors	*included above*	External doors	*included above*
		£10,822.40		£10,822.40		£10,822.40		£10,822.40
Finishes, fixtures & fittings	Internal doors	£10,000.00	Internal doors	£10,000.00	Internal doors	£10,000.00	Internal doors	£10,000.00
	Floor finishes	£450.00	Floor finishes	£450.00	Floor finishes	£450.00	Floor finishes	£450.00
	Wall finishes	£6,300.00	Wall finishes	£6,300.00	Wall finishes	£6,300.00	Wall finishes	£6,300.00
	Ceiling finishes	£1,497.60	Ceiling finishes	£1,497.60	Ceiling finishes	£1,497.60	Ceiling finishes	£1,497.60
	Kitchen F&F	£12,000.00	Kitchen F&F	£12,000.00	Kitchen F&F	£12,000.00	Kitchen F&F	£12,000.00
	Bath & Toilet F&F	£7,000.00	Bath & Toilet F&F	£7,000.00	Bath & Toilet F&F	£7,000.00	Bath & Toilet F&F	£7,000.00
		£37,247.60		£37,247.60		£37,247.60		£37,247.60
M&E	General electrical circuit	£11,000.00	General electrical circuit	£11,000.00	General electrical circuit	£11,000.00	General electrical circuit	£11,000.00
	ASHPs w/ cylinders	£32,000.00	ASHPs w/ cylinders	£32,000.00	ASHPs w/ cylinders	£32,000.00	ASHPs w/ cylinders	£32,000.00
	MEV units (3 per unit)	£1,800.00	MEV units (3 per unit)	£1,800.00	MEV units (3 per unit)	£1,800.00	MEV units (3 per unit)	£1,800.00
	PV panels (19 per unit)	£16,000.00	PV panels (19 per unit)	£16,000.00	PV panels (19 per unit)	£16,000.00	PV panels (19 per unit)	£16,000.00
		£60,800.00		£60,800.00		£60,800.00		£60,800.00
Preliminaries (12.5%)		£33,991.31		£36,421.00		£38,112.88		£39,270.38
TOTAL		£305,921.81	+7% uplift	£327,789.00	+12% uplift	£343,015.88	+16% uplift	£353,433.38

HT 421 AD: L cost analysis headlines

- 16% capital cost uplift can reduce cradle-to-grave embodied carbon 30% (RIBA/ RIAI and LETI) & upfront carbon emissions c. 30% (LETI)
- Cost uplifts (regularised roof finish):
  - Masonry to Framed: 6%
  - Masonry to Timber: 10%
  - Masonry to Timber Opt.: 6%
- Party walls largest single contributor to uplift in cost for timber construction

Critical components of the structure and thermal envelope highlighted in green are essential to achieving the necessary fabric u-values.

Highlighting the thermal elements demonstrates the perceived 16% uplift between Scenarios 1 and 4 is primarily attributable to elements that do not form part of the thermal envelope. Party walls, Internal walls and the roof finish produce the most pronounced cost differences; changing the External walls from masonry only adds 9-12% to this particular line item and c. 2% to total construction costs.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue.

Construction to LETI	Scenario 1: Masonry		Scenario 2: Framed		Scenario 3: Timber		Scenario 4: Timber Optimised	
Foundations	Concrete trench fill	£13,000.00	Concrete trench fill	£13,000.00			Concrete trench fill	£13,000.00
		£13,000.00		£13,000.00				£13,000.00
Ground floor	Sand & cement screed	£4,400.00	Sand & cement screed	£4,400.00	Reinforced concrete raft	£24,750.00	Chipboard floor finish	£2,750.00
	PIR insulation	£9,900.00	XPS insulation	£9,900.00	Jackon XPS formwork	£13,750.00	STEICOjoist w/ WarmCel	£9,350.00
	Concrete slab	£14,850.00	Beam & block floor	£11,000.00				
		£29,150.00		£25,300.00		£38,500.00		£12,100.00
External walls	Plasterboard w/ skim	£5,460.00	Plasterboard w/ skim	£5,460.00	Plasterboard w/ skim	£5,460.00	Plasterboard w/ skim	£5,460.00
	Battened service zone	£910.00	Battened service zone	£910.00	Battened service zone	£910.00	Battened service zone	£910.00
	Passive Purple VCL	£3,640.00	PIR insulation	£10,010.00	SmartPly ProPassiv OSB	£4,550.00	SmartPly ProPassiv OSB	£4,550.00
	Concrete blockwork	£14,880.00	SmartPly ProPassiv OSB	£4,550.00	Timber stud w/ Gutex	£24,800.00	Twin studs w/ WarmCel	£31,000.00
	PIR insulation	£17,360.00	Timber stud w/ Isover 32	£18,600.00	Gutex Multitherm	£13,640.00	Panelvent sheathing board	£8,680.00
	Ventilated cavity	£248.00	Panelvent sheathing board	£8,680.00	Ventilated cavity	£248.00	Ventilated cavity	£428.00
	Brickwork	£24,800.00	Ventilated cavity	£248.00	Brickwork	£24,800.00	Brickwork	£24,800.00
			Brickwork	£24,800.00				
		£67,298.00		£73,258.00		£74,408.00		£75,648.00
Party walls	Sand & cement plaster	£975.00	Plasterboard w/ skim	£1,755.00	Plasterboard w/ skim	£1,755.00	Plasterboard w/ skim	£1,755.00
	Blockwork	£1,560.00	Timber stud w/ Isover 32	£2,535.00	Smartply ProPassiv OSB	£975.00	Smartply ProPassiv OSB	£975.00
	Rockwool filled cavity	£292.50	Smartply ProPassiv OSB	£975.00	Timber stud w/ WarmCel	£3,705.00	Timber stud w/ WarmCel	£3,705.00
	Blockwork	£1,950.00	Isover 32 filled cavity	£1,170.00	OSB sheathing	£780.00	OSB sheathing	£780.00
	Sand & cement plaster	£975.00	Smartply ProPassiv OSB	£975.00	WarmCel filled cavity	£1,755.00	WarmCel filled cavity	£1,755.00
			Timber stud w/ Isover 32	£2,535.00	OSB sheathing	£780.00	OSB sheathing	£780.00
			Plasterboard w/ skim	£1,755.00	Timber stud w/ WarmCel	£3,705.00	Timber stud w/ WarmCel	£3,705.00
					Smartply ProPassiv OSB	£975.00	Smartply ProPassiv OSB	£975.00
					Plasterboard w/ skim	£1,755.00	Plasterboard w/ skim	£1,755.00
		£5,752.50		£11,700.00		£16,185.00		£16,185.00
Internal walls	Sand & cement plaster	£3,150.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00
	Blockwork	£9,000.00	Timber stud w/ Isover 32	£11,700.00	Timber stud w/ Gutex	£11,700.00	Timber stud w/ WarmCel	£15,300.00
	Sand & cement plaster	£3,150.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£5,400.00	Plasterboard w/ skim	£15,400.00
		£15,300.00		£22,500.00		£22,500.00		£26,100.00
Intermediate floor	Chipboard floor finish	£2,200.00	Chipboard floor finish	£2,200.00	Chipboard floor finish	£2,200.00	Chipboard floor finish	£2,200.00
	W. joists w/ Rockwool	£3,520.00	W. joists w/ Earthwool	£4,400.00	W. joists w/ Gutex	£4,400.00	W. joists w/ WarmCel	£5,720.00
	Plasterboard with skim	£2,640.00	Plasterboard with skim	£2,640.00	Plasterboard with skim	£2,640.00	Plasterboard with skim	£2,640.00
		£8,360.00		£9,240.00		£9,240.00		£10,560.00
Roof	Plasterboard w/ skim	£2,640.00	Plasterboard w/ skim	£2,640.00	Plasterboard w/ skim	£2,640.00	Plasterboard w/ skim	£2,640.00
	Battened service zone	£1,100.00	Battened service zone	£1,100.00	Battened service zone	£1,100.00	Battened service zone	£1,100.00
	Rockwool insulation	£5,500.00	Earthwool insulation	£6,600.00	SmartPly ProPassiv OSB	£2,750.00	SmartPly ProPassiv OSB	£2,750.00
	Timber trusses	£8,250.00	Timber trusses	£8,250..00	Indinature hemp insulation	£8,250.00	WarmCel insulation	£7,150.00
	Ventilated attic	£110.00	Ventilated attic	£110.00	Timber trusses	£8,250.00	Timber trusses	£8,250.00
	Tile battens	£2,200.00	Tile battens	£2,200.00	Ventilated attic	£110.00	Ventilated attic	£110.00
	Concrete tiles	£4,400.00	Clay tiles	£6,600.00	Tile battens	£2,200.00	Tile battens	£2,200.00
					Spanish slate	£9,900.00	Welsh slate	£27,500.00
		£24,200.00		£27,500.00		£35,200.00		£51,700.00
External doors & windows	Rehau Artevo TG	£11,814.16	Rehau Artevo TG	£11,814.16	Rehau Artevo TG	£11,814.16	Rehau Artevo TG	£11,814.16
	External doors	*included above*	External doors	*included above*	External doors	*included above*	External doors	*included above*
	+9% uplift vs. AD L	£11,814.16	+9% uplift vs. AD L	£11,814.16	+9% uplift vs. AD L	£11,814.16	+9% uplift vs. AD L	£11,814.16
Finishes, fixtures & fittings	Internal doors	£10,000.00	Internal doors	£10,000.00	Internal doors	£10,000.00	Internal doors	£10,000.00
	Floor finishes	£450.00	Floor finishes	£450.00	Floor finishes	£450.00	Floor finishes	£450.00
	Wall finishes	£6,300.00	Wall finishes	£6,300.00	Wall finishes	£6,300.00	Wall finishes	£6,300.00
	Ceiling finishes	£1,497.60	Ceiling finishes	£1,497.60	Ceiling finishes	£1,497.60	Ceiling finishes	£1,497.60
	Kitchen F&F	£12,000.00	Kitchen F&F	£12,000.00	Kitchen F&F	£12,000.00	Kitchen F&F	£12,000.00
	Bath & Toilet F&F	£7,000.00	Bath & Toilet F&F	£7,000.00	Bath & Toilet F&F	£7,000.00	Bath & Toilet F&F	£7,000.00
		£37,247.60		£37,247.60		£37,247.60		£37,247.60
M&E	General electrical circuit	£11,000.00	General electrical circuit	£11,000.00	General electrical circuit	£11,000.00	General electrical circuit	£11,000.00
	ASHPs w/ cylinders	£24,000.00	ASHPs w/ cylinders	£24,000.00	ASHPs w/ cylinders	£24,000.00	ASHPs w/ cylinders	£24,000.00
	Zehnder MVHR units	£7,000.00	Zehnder MVHR units	£7,000.00	Zehnder MVHR units	£7,000.00	Zehnder MVHR units	£7,000.00
	PV panels (12 per unit)	£14,400.00	PV panels (12 per unit)	£14,400.00	PV panels (12 per unit)	£14,400.00	PV panels (12 per unit)	£14,400.00
	9% saving vs AD L	£45,400.00	9% saving vs AD L	£45,400.00	9% saving vs AD L	£45,400.00	9% saving vs AD L	£45,400.00
Preliminaries (12.5%)		£33,565.28		£35,994.97		£37,686.85		£38,844.35
TOTAL	1% saving vs AD L	£302,087.54	1% saving vs AD L	£323,954.73	1% saving vs AD L	£339,181.61	1% saving vs AD L	£349,599.11

HT 421 LETI cost analysis headlines

- Window cost difference negligible
- MVHR adds capital uplift but also improves operational performance, reducing heating demand and EUI
- ASHP reduce from 5 kW to 3.5 kW due to reduced space heating demand
- Lower EUI enables PV provision to reduce 40% and achieve Net Zero
- Small capital cost savings realised
- Operational costs decrease c. 35%

Critical components of the structure and thermal envelope highlighted in green are essential to achieving the necessary fabric u-values. As previous commentary there is no difference between the fabric (except windows) for the two operational scenarios.

Windows have been upgraded from double to triple glazing for this scenario, costing an extra c. £990.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue.

While installing MVHR presents a capital cost uplift versus MEV it contributes to reducing space heating demand and EUI. Associated additional costs must be considered against the cost savings realised with these operational improvements: reduced ASHP costs changing from 5 kW to 3.5 kW units, 7 fewer photovoltaic panels per dwelling and greatly reduced operational costs for occupants.

Overall there is a c. 1% capital cost saving to upgrade AD: L (Wales) 2025 to the LETI operational scenario while running costs would decrease c. 35%.

spring design

3.1.3 HT 641

This section contains a summary of the operational and embodied assessment of **HT 641** with high-level costings followed by detailed cost analyses on pages 19-20. For illustrative drawings of the building and its modelled context, please refer to 5: Appendices.

Operational outputs demonstrate the potential to reduce space heating demand more than 80% by improving from AD: L (Wales) 2025 to LETI operational scenarios. This results in a 30% reduction in EUI, potential CO_2e emissions and the number of photovoltaics required to achieve Net Zero.

This typology does not manage to achieve the targeted EUI of 40 kWh/m²/yr. Representing the least efficient of the modelled typologies, it was considered most appropriate to allow this to fail rather than adjust or customise the residential specification to pass.

Embodied outputs and the colour-coded LETI diagram demonstrate the relative carbon intensities of the modelled construction scenarios. Excluding internal finishes and fittings, all timber scenarios achieve RIBA/RIAI 2030 targets but all fail to meet LETI 2030 upfront emission target of 300 kgCO_2e/m².

Twin Stud Cellulose (Scenario 4) delivers the lowest carbon intensity, prioritising short-term rotation and recycled biogenic materials, reducing upfront carbon 6% more than other timber options and 30% more than masonry with 2.8x more carbon sequestered. For this typology the sequestered carbon of Twin Stud Cellulose almost equals upfront carbon emissions.

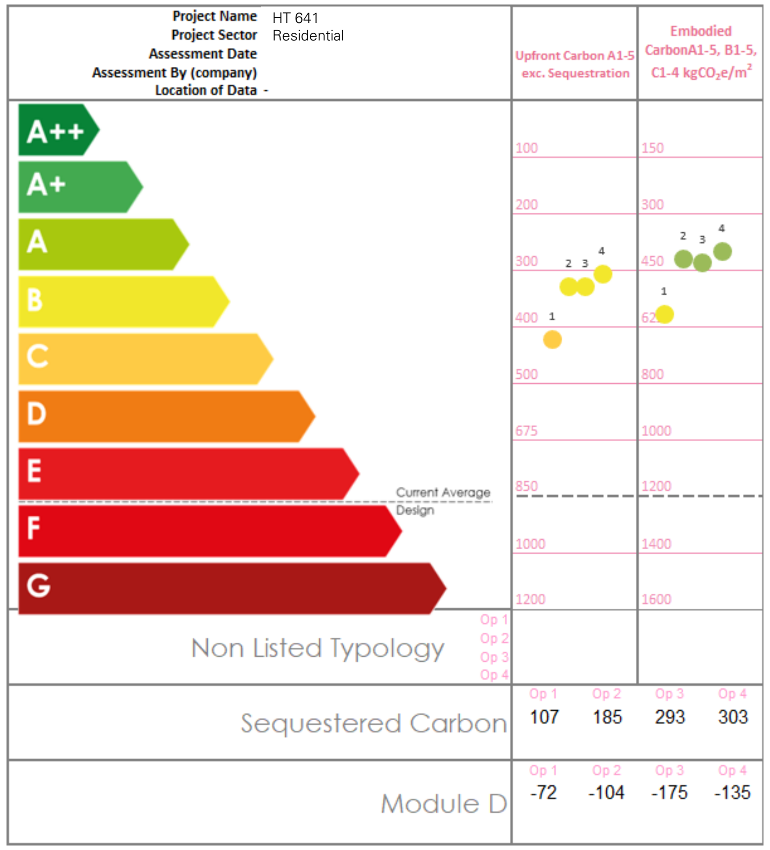
Cost Analysis to LETI presents the breakdown of costs apportioned to various building components for the four scenarios. This shows that masonry - the most carbon intensive scenario - is the cheapest to build with an uplift of 4% associated with changing to timber frame and 3-7% employing timber frame with biogenic insulants when roof coverings are regularised. A large portion of the residual uplift can be assigned to the internal walls which could be value engineered to deliver a more cost-effective solution. The narrowing margins suggest the advantages attributable to building with timber might make it the more favourable methodology for this typology. Additional costs would be quickly offset by achieving an accelerated build programme with greater on-site flexibility and the ability to incorporate MMC.

Operational outputs - HT 641					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	CO_2e emissions ex. PV (60 yrs)	kWp of PV to Net Zero per dwelling
1 AD: L (Wales) 2025	79.5 kWh/m²/yr	65.6 kWh/m²/yr	7,242 kWh	27.20 tonnes	10.0 kWp
2 AECB CarbonLite	35.8 kWh/m²/yr	48.4 kWh/m²/yr	5,343 kWh	20.10 tonnes	7.4 kWp
3 B&NES	27.3 kWh/m²/yr	46.3 kWh/m²/yr	5,112 kWh	19.20 tonnes	7.0 kWp
4 LETI	15.1 kWh/m²/yr	44.5 kWh/m²/yr	4,913 kWh	18.50 tonnes	6.8 kWp

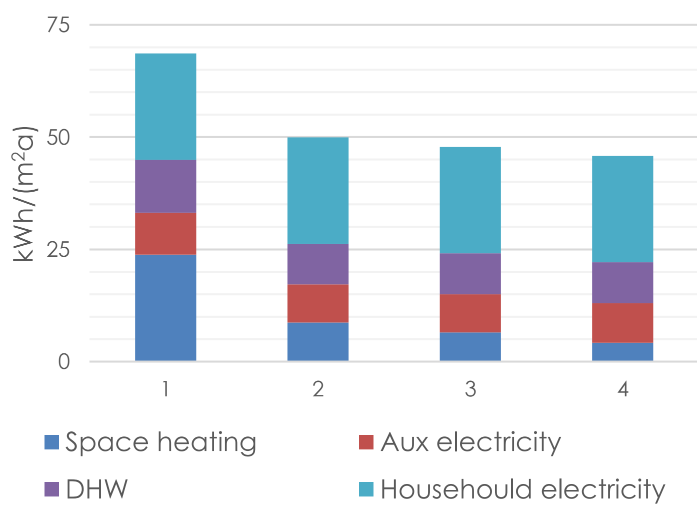
Embodied outputs - HT 641					
		LETI			
Option	RIBA/ RIAI (cradle to grave)	Upfront carbon A1-5	Embodied carbon A1-5, B1-5, C1-4	Sequestered carbon	Module D (offsite benefits)
1 Masonry	748 kgCO_2e/m²	422 kgCO_2e/m²	589 kgCO_2e/m²	107 kgCO_2e/m²	-72 kgCO_2e/m²
2 Framed	580 kgCO_2e/m²	327 kgCO_2e/m²	420 kgCO_2e/m²	185 kgCO_2e/m²	-104 kgCO_2e/m²
3 Timber	593 kgCO_2e/m²	326 kgCO_2e/m²	433 kgCO_2e/m²	293 kgCO_2e/m²	-175 kgCO_2e/m²
4 Timber Optimised	560 kgCO_2e/m²	305 kgCO_2e/m²	400 kgCO_2e/m²	303 kgCO_2e/m²	-135 kgCO_2e/m²

Cost Analysis to LETI				
Construction	Scenario 1: Masonry	Scenario 2: Framed	Scenario 3: Timber	Scenario 4: Timber Opt.
Foundations	£8,750.00	£8,750.00	£25,550.00	£8,750.00
Ground floor	£19,345.00	£16,790.00		£8,030.00
External walls	£54,230.00	£58,990.00	£59,960.00	£60,960.00
Internal walls	£9,435.00	£13,875.00	£13,875.00	£16,095.00
Intermediate floor	£5,225.00	£5,775.00	£5,775.00	£6,600.00
Roof	£15,958.00	£18,148.00	£23,258.00	£34,208.00
Doors & windows	£7,642.39	£7,642.39	£7,642.39	£7,642.39
FF&F	£22,865.60	£22,865.60	£22,865.60	£22,865.60
M&E	£33,300.00	£33,300.00	£33,300.00	£33,300.00
Preliminaries	£22,093.87	£23,267.00	£24,028.25	£24,806.37
TOTAL	**£198,844.86**	**£209,402.99**	**£216,254.24**	**£223,257.36**
Cost per unit	£198,844.86	£209,402.99	£216,254.24	£223,257.36
Cost per m²	£1,801.13	£1,896.77	£1,958.82	£2,022.26

LETI embodied carbon reporting - HT 641

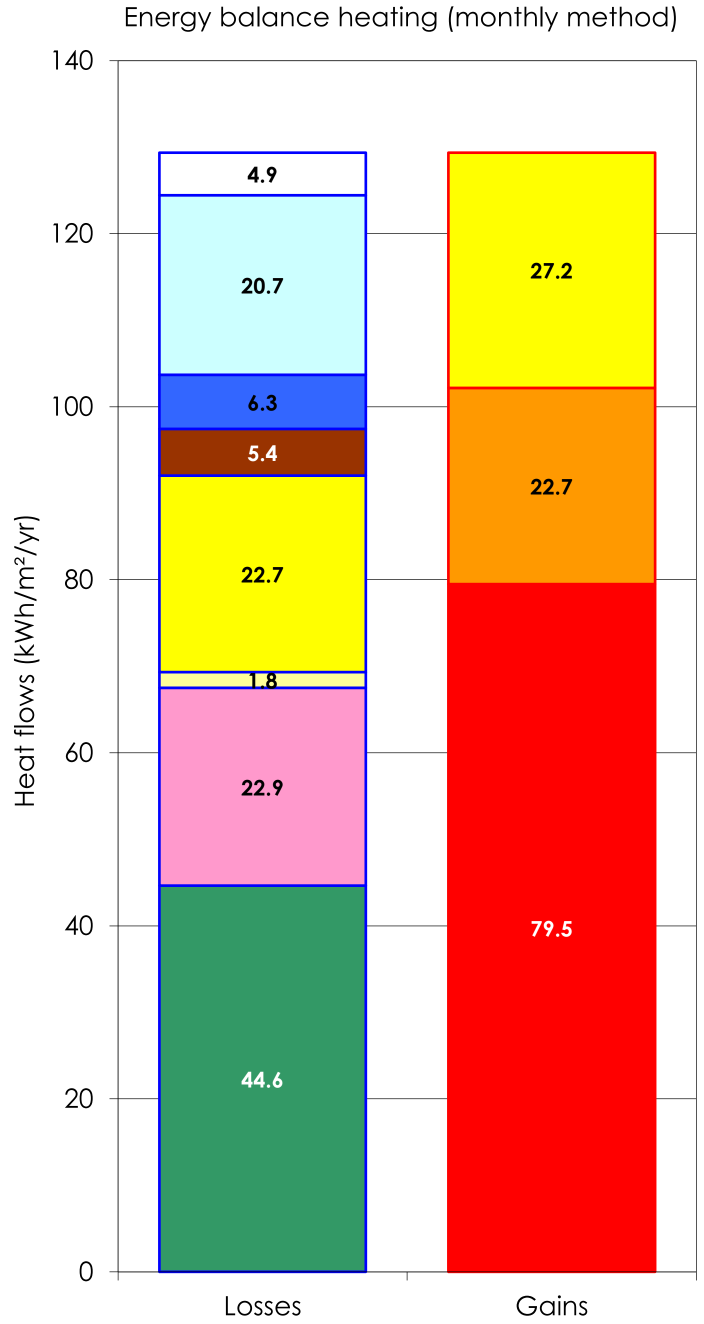


Energy consumption by use - HT 641

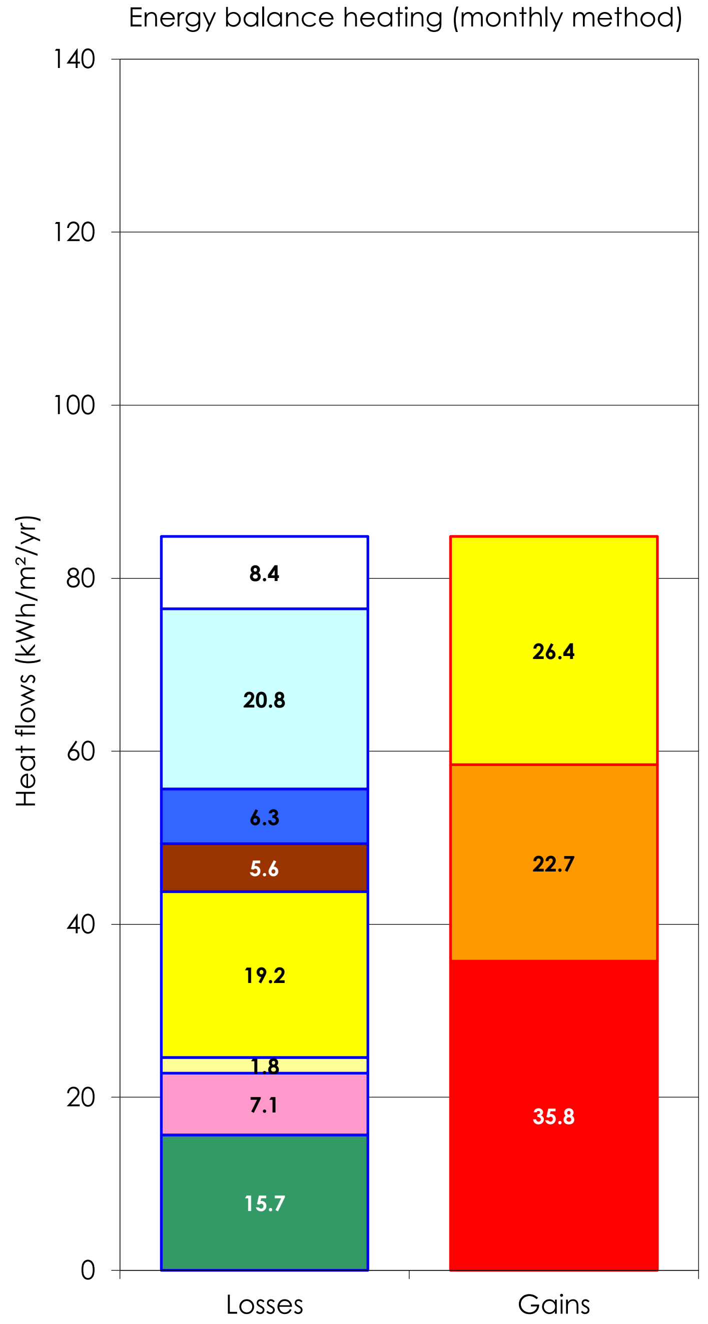


Operational Scenarios

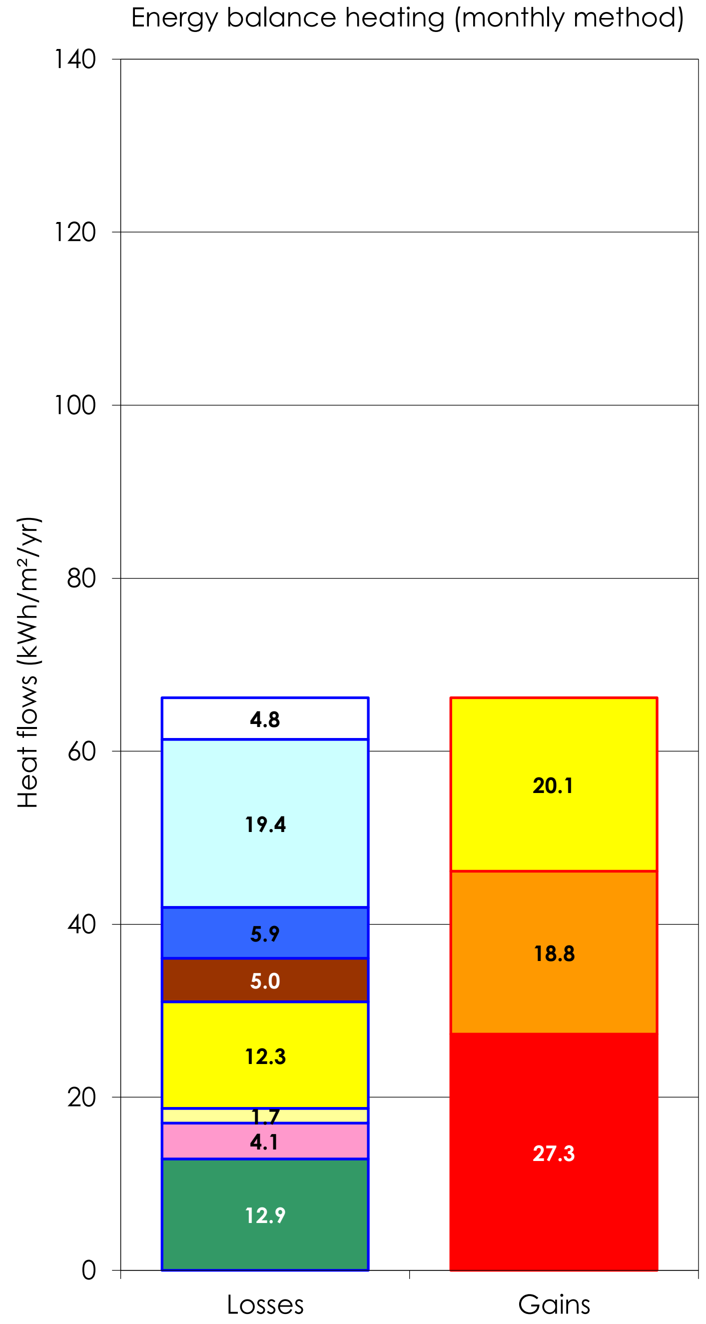
HT 641 - AD: L (Wales) 2025



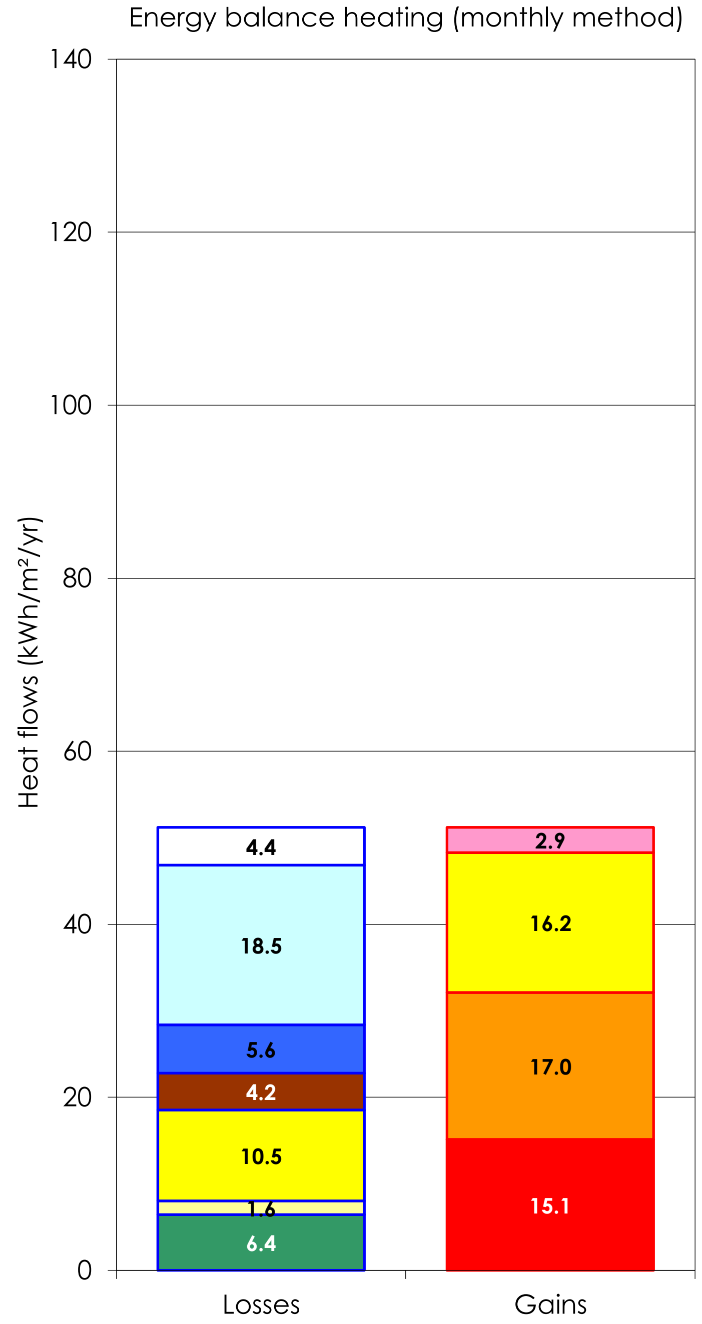
HT 641 - AECB CarbonLite



HT 641 - B&NES



HT 641 - LETI



- Non-useful gains
- External walls
- Roof/ ceiling
- Floor slab
- Windows
- External door
- Thermal bridges
- Ventilation
- Thermal bridges
- Solar gains
- Internal gains
- Heating demand

This page contains the energy balance from PHPP for the four energy scenarios. These graphical outputs illustrate where both heat losses and gains - which must be balanced to maintain a stable, comfortable internal temperature - occur: this information can be used to interrogate the performance of the building fabric and optimise specifications.

Annual energy bills calculated by multiplying EUI by Ofgem Q2 2024 electricity unit rate of £0.245 per kWh

Projected annual electricity bills

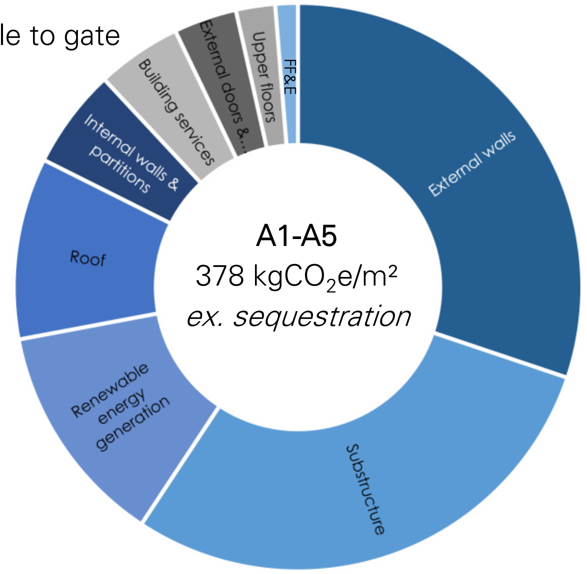
- AD:L (Wales) 2025 £1,774.29
- AECB CarbonLite £1,309.04
- B&NES £1,252.44
- LETI £1,203.69

excludes standing charge & PV offsets

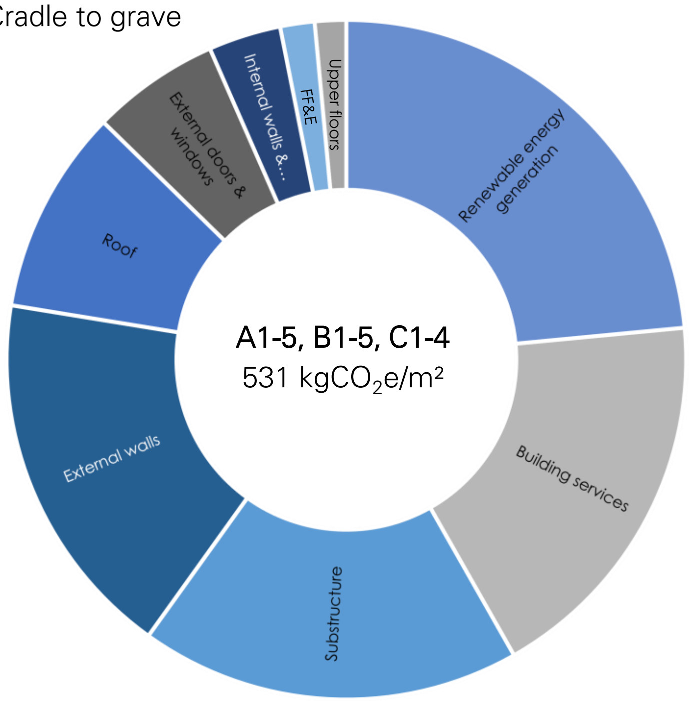
Embodied Scenarios

HT 641 - Scenario 1
Masonry: Masonry with PIR
diagrams exclude groundworks

Cradle to gate

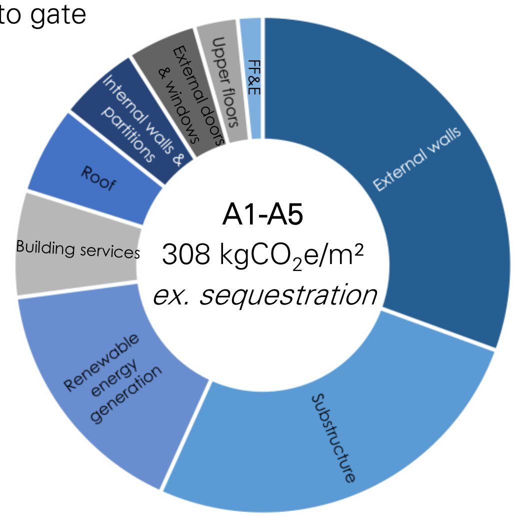


Cradle to grave

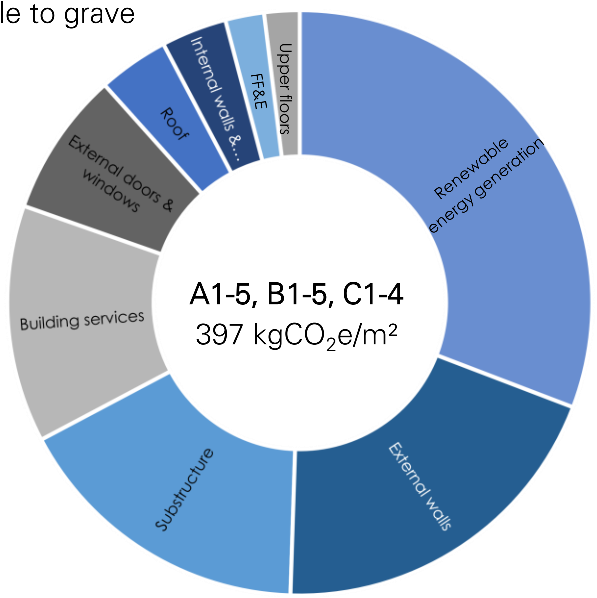


HT 641 - Scenario 2
Framed: 140mm Stud Mineral Wool & PIR
diagrams exclude groundworks

Cradle to gate

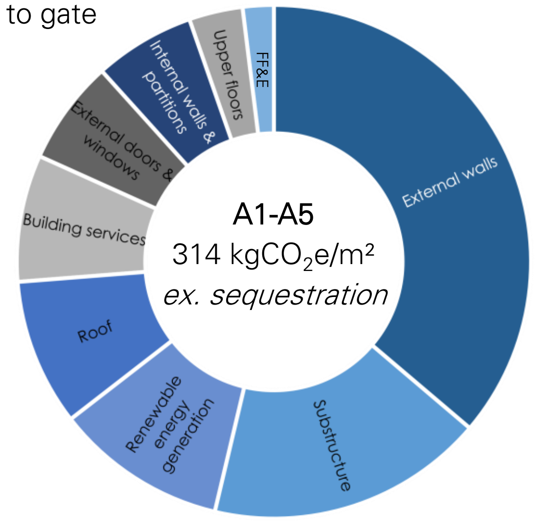


Cradle to grave

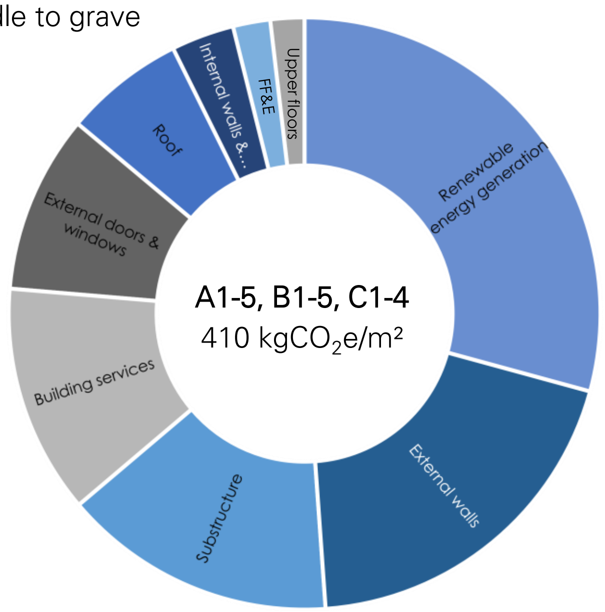


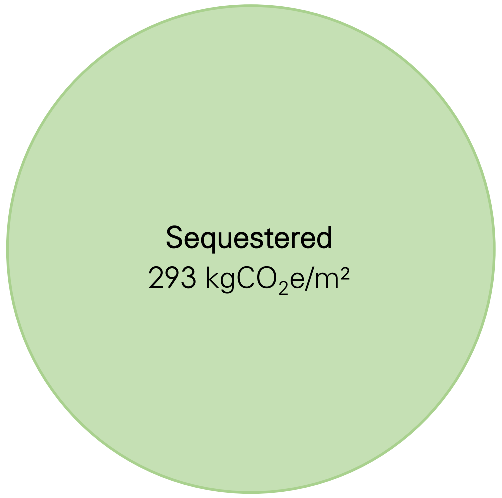
HT 641 - Scenario 3
Timber: 140mm Stud Woodfibre
diagrams exclude groundworks

Cradle to gate



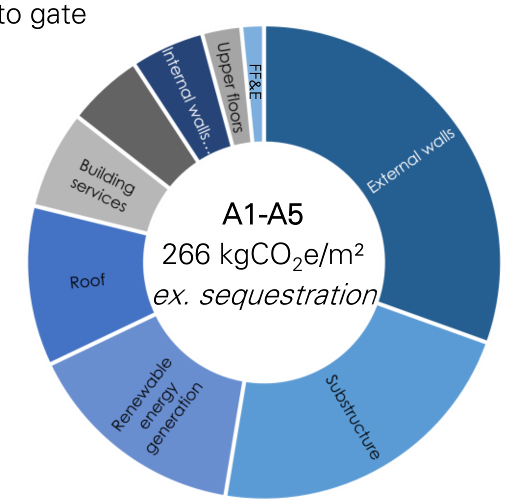
Cradle to grave



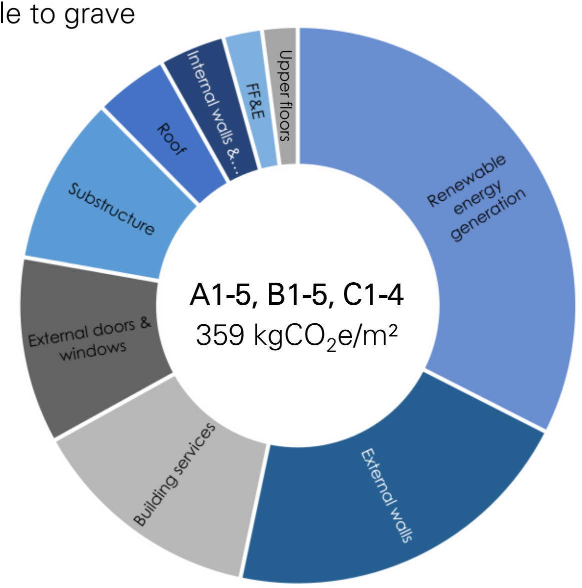


HT 641 - Scenario 4
Timber Optimised: Twin Stud Cellulose
diagrams exclude groundworks

Cradle to gate



Cradle to grave



Construction to AD: L (Wales)	Scenario 1: Masonry		Scenario 2: Framed		Scenario 3: Timber		Scenario 4: Timber Optimised	
Foundations	Concrete trench fill	£8,750.00	Concrete trench fill	£8,750.00			Concrete trench fill	£8,750.00
		£8,750.00		£8,750.00				£8,750.00
Ground floor	Sand & cement screed	£2,920.00	Sand & cement screed	£2,920.00	Reinforced concrete raft	£16,425.00	Chipboard floor finish	£1,825.00
	PIR insulation	£6,570.00	XPS insulation	£6,570.00	Jackon XPS formwork	£9,125.00	STEICOjoist w/ WarmCel	£6,205.00
	Concrete slab	£9,855.00	Beam & block floor	£7,300.00				
		£19,345.00	13% saving	£16,790.00	9% cumulative saving	£25,550.00	58% saving	£8,030.00
External walls	Plasterboard w/ skim	£4,380.00	Plasterboard w/ skim	£4,380.00	Plasterboard w/ skim	£4,380.00	Plasterboard w/ skim	£4,380.00
	Battened service zone	£730.00	Battened service zone	£730.00	Battened service zone	£730.00	Battened service zone	£730.00
	Passive Purple VCL	£2,920.00	PIR insulation	£8,030.00	SmartPly ProPassiv OSB	£3,650.00	SmartPly ProPassiv OSB	£3,650.00
	Concrete blockwork	£12,000.00	SmartPly ProPassiv OSB	£3,650.00	Timber stud w/ Gutex	£20,000.00	Twin studs w/ WarmCel	£25,00.00
	PIR insulation	£14,000.00	Timber stud w/ Isover 32	£15,000.00	Gutex Multitherm	£11,000.00	Panelvent sheathing board	£7,000.00
	Ventilated cavity	£200.00	Panelvent sheathing board	£7,000.00	Ventilated cavity	£200.00	Ventilated cavity	£200.00
	Brickwork	£20,000.00	Ventilated cavity	£200.00	Brickwork	£20,000.00	Brickwork	£20,000.00
			Brickwork	£20,000.00				
		£54,230.00	+9% uplift	£58,990.00	+11% uplift	£59,960.00	+12% uplift	£60,960.00
Internal walls	Sand & cement plaster	£1,942.50	Plasterboard w/ skim	£3,330.00	Plasterboard w/ skim	£3,330.00	Plasterboard w/ skim	£3,330.00
	Blockwork	£5,550.00	Timber stud w/ Isover 32	£7,215.00	Timber stud w/ Gutex	£7,215.00	Timber stud w/ WarmCel	£9,435.00
	Sand & cement plaster	£1,942.50	Plasterboard w/ skim	£3,330.00	Plasterboard w/ skim	£3,330.00	Plasterboard w/ skim	£3,330.00
		£9,435.00	+47% uplift	£13,875.00	+47% uplift	£13,875.00	+71% uplift	£16,095.00
Intermediate floor	Chipboard floor finish	£1,375.00	Chipboard floor finish	£1,375.00	Chipboard floor finish	£1,375.00	Chipboard floor finish	£1,375.00
	W. joists w/ Rockwool	£2,200.00	W. joists w/ Earthwool	£2,750.00	W. joists w/ Gutex	£2,750.00	W. joists w/ WarmCel	£3,575.00
	Plasterboard with skim	£1,650.00	Plasterboard with skim	£1,650.00	Plasterboard with skim	£1,650.00	Plasterboard with skim	£1,650.00
		£5,225.00	+11% uplift	£5,775.00	+11% uplift	£5,775.00	+26% uplift	£6,600.00
Roof	Plasterboard w/ skim	£1,650.00	Plasterboard w/ skim	£1,650.00	Plasterboard w/ skim	£1,650.00	Plasterboard w/ skim	£1,650.00
	Battened service zone	£730.00	Battened service zone	£730.00	Battened service zone	£730.00	Battened service zone	£730.00
	Rockwool insulation	£3,650.00	Earthwool insulation	£4,380.00	SmartPly ProPassiv OSB	£1,825.00	SmartPly ProPassiv OSB	£1,825.00
	Timber trusses	£5,475.00	Timber trusses	£5,475..00	Indinature hemp insulation	£5,475.00	WarmCel insulation	£4,745.00
	Ventilated attic	£73.00	Ventilated attic	£73.00	Timber trusses	£5,475.00	Timber trusses	£5,475.00
	Tile battens	£1,460.00	Tile battens	£1,460.00	Ventilated attic	£73.00	Ventilated attic	£73.00
	Concrete tiles	£2,920.00	Clay tiles	£4,380.00	Tile battens	£1,460.00	Tile battens	£1,460.00
					Spanish slate	£6,570.00	Welsh slate	£18,250.00
		£15,958.00	+14% uplift	£18,148.00	+46% uplift	£23,258.00	+114% uplift	£34,208.00
External doors & windows	Rehau Artevo TG	£7,018.76	Rehau Artevo TG	£7,018.76	Rehau Artevo TG	£7,018.76	Rehau Artevo TG	£7,018.76
	External doors	*included above*	External doors	*included above*	External doors	*included above*	External doors	*included above*
		£7,018.76		£7,018.76		£7,018.76		£7,018.76
Finishes, fixtures & fittings	Internal doors	£6,000.00	Internal doors	£6,000.00	Internal doors	£6,000.00	Internal doors	£6,000.00
	Floor finishes	£270.00	Floor finishes	£270.00	Floor finishes	£270.00	Floor finishes	£270.00
	Wall finishes	£3,312.00	Wall finishes	£3,312.00	Wall finishes	£3,312.00	Wall finishes	£3,312.00
	Ceiling finishes	£993.60	Ceiling finishes	£993.60	Ceiling finishes	£993.60	Ceiling finishes	£993.60
	Kitchen & Utility F&F	£8,250.00	Kitchen & Utility F&F	£8,250.00	Kitchen & Utility F&F	£8,250.00	Kitchen & Utility F&F	£8,250.00
	Bath & Wet Room F&F	£3,500.00	Bath & Wet Room F&F	£3,500.00	Bath & Wet Room F&F	£3,500.00	Bath & Wet Room F&F	£3,500.00
		£22,865.60		£22,865.60		£22,865.60		£22,865.60
M&E	General electrical circuit	£6,500.00	General electrical circuit	£6,500.00	General electrical circuit	£6,500.00	General electrical circuit	£6,500.00
	ASHP w/ cylinder	£18,000.00	ASHP w/ cylinder	£18,000.00	ASHP w/ cylinder	£18,000.00	ASHP w/ cylinder	£18,000.00
	MEV units (4 per unit)	£1,200.00	MEV units (4 per unit)	£1,200.00	MEV units (4 per unit)	£1,200.00	MEV units (4 per unit)	£1,200.00
	PV panels (25 per unit)	£10,800.00	PV panels (25 per unit)	£10,800.00	PV panels (25 per unit)	£10,800.00	PV panels (25 per unit)	£10,800.00
		£37,700.00		£37,700.00		£37,700.00		£37,700.00
Preliminaries (12.5%)		£22,093.87		£23,267.00		£24,028.25		£24,806.37
TOTAL		£203,093.28	+5% uplift	£213,651.41	+9% uplift	£220,502.66	+12% uplift	£227,505.78

HT 641 AD: L cost analysis headlines

- 12% capital cost uplift can reduce cradle-to-grave embodied carbon 25% (RIBA/ RIAI and LETI) & upfront carbon emissions c. 27% (LETI)
- Cost uplifts (regularised roof finish):
  - Masonry to Framed: 4%
  - Masonry to Timber: 6%
  - Masonry to Timber Opt.: 3%
- Internal walls largest single contributor to uplift in cost for timber construction

Critical components of the structure and thermal envelope highlighted in green are essential to achieving the necessary fabric u-values.

Highlighting the thermal elements demonstrates the perceived 12% uplift between Scenarios 1 and 4 is primarily attributable to elements that do not form part of the thermal envelope. Internal walls and the roof finish produce the most pronounced cost differences; changing the External walls from masonry only adds c. 9-12% to this particular line item and c. 3% to total construction costs.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue.

spring design

Construction to LETI	Scenario 1: Masonry		Scenario 2: Framed		Scenario 3: Timber		Scenario 4: Timber Optimised	
Foundations	Concrete trench fill	£8,750.00	Concrete trench fill	£8,750.00			Concrete trench fill	£8,750.00
		£8,750.00		£8,750.00				£8,750.00
Ground floor	Sand & cement screed	£2,920.00	Sand & cement screed	£2,920.00	Reinforced concrete raft	£16,425.00	Chipboard floor finish	£1,825.00
	PIR insulation	£6,570.00	XPS insulation	£6,570.00	Jackon XPS formwork	£9,125.00	STEICOjoist w/ WarmCel	£6,205.00
	Concrete slab	£9,855.00	Beam & block floor	£7,300.00				
		£19,345.00		£16,790.00		£25,550.00		£8,030.00
External walls	Plasterboard w/ skim	£4,380.00	Plasterboard w/ skim	£4,380.00	Plasterboard w/ skim	£4,380.00	Plasterboard w/ skim	£4,380.00
	Battened service zone	£730.00	Battened service zone	£730.00	Battened service zone	£730.00	Battened service zone	£730.00
	Passive Purple VCL	£2,920.00	PIR insulation	£8,030.00	SmartPly ProPassiv OSB	£3,650.00	SmartPly ProPassiv OSB	£3,650.00
	Concrete blockwork	£12,000.00	SmartPly ProPassiv OSB	£3,650.00	Timber stud w/ Gutex	£20,000.00	Twin studs w/ WarmCel	£25,00.00
	PIR insulation	£14,000.00	Timber stud w/ Isover 32	£15,000.00	Gutex Multitherm	£11,000.00	Panelvent sheathing board	£7,000.00
	Ventilated cavity	£200.00	Panelvent sheathing board	£7,000.00	Ventilated cavity	£200.00	Ventilated cavity	£200.00
	Brickwork	£20,000.00	Ventilated cavity	£200.00	Brickwork	£20,000.00	Brickwork	£20,000.00
			Brickwork	£20,000.00				
		£54,230.00		£58,990.00		£59,960.00		£60,960.00
Internal walls	Sand & cement plaster	£1,942.50	Plasterboard w/ skim	£3,330.00	Plasterboard w/ skim	£3,330.00	Plasterboard w/ skim	£3,330.00
	Blockwork	£5,550.00	Timber stud w/ Isover 32	£7,215.00	Timber stud w/ Gutex	£7,215.00	Timber stud w/ WarmCel	£9,435.00
	Sand & cement plaster	£1,942.50	Plasterboard w/ skim	£3,330.00	Plasterboard w/ skim	£3,330.00	Plasterboard w/ skim	£3,330.00
		£9,435.00		£13,875.00		£13,875.00		£16,095.00
Intermediate floor	Chipboard floor finish	£1,375.00	Chipboard floor finish	£1,375.00	Chipboard floor finish	£1,375.00	Chipboard floor finish	£1,375.00
	W. joists w/ Rockwool	£2,200.00	W. joists w/ Earthwool	£2,750.00	W. joists w/ Gutex	£2,750.00	W. joists w/ WarmCel	£3,575.00
	Plasterboard with skim	£1,650.00	Plasterboard with skim	£1,650.00	Plasterboard with skim	£1,650.00	Plasterboard with skim	£1,650.00
		£5,225.00		£5,775.00		£5,775.00		£6,600.00
Roof	Plasterboard w/ skim	£1,650.00	Plasterboard w/ skim	£1,650.00	Plasterboard w/ skim	£1,650.00	Plasterboard w/ skim	£1,650.00
	Battened service zone	£730.00	Battened service zone	£730.00	Battened service zone	£730.00	Battened service zone	£730.00
	Rockwool insulation	£3,650.00	Earthwool insulation	£4,380.00	SmartPly ProPassiv OSB	£1,825.00	SmartPly ProPassiv OSB	£1,825.00
	Timber trusses	£5,475.00	Timber trusses	£5,475..00	Indinature hemp insulation	£5,475.00	WarmCel insulation	£4,745.00
	Ventilated attic	£73.00	Ventilated attic	£73.00	Timber trusses	£5,475.00	Timber trusses	£5,475.00
	Tile battens	£1,460.00	Tile battens	£1,460.00	Ventilated attic	£73.00	Ventilated attic	£73.00
	Concrete tiles	£2,920.00	Clay tiles	£4,380.00	Tile battens	£1,460.00	Tile battens	£1,460.00
					Spanish slate	£6,570.00	Welsh slate	£18,250.00
		£15,958.00		£18,148.00		£23,258.00		£34,208.00
External doors & windows	Rehau Artevo TG	£7,642.39	Rehau Artevo TG	£7,642.39	Rehau Artevo TG	£7,642.39	Rehau Artevo TG	£7,642.39
	External doors	*included above*	External doors	*included above*	External doors	*included above*	External doors	*included above*
	+9% uplift vs. AD L	£7,642.39	+9% uplift vs. AD L	£7,642.39	+9% uplift vs. AD L	£7,642.39	+9% uplift vs. AD L	£7,642.39
Finishes, fixtures & fittings	Internal doors	£6,000.00	Internal doors	£6,000.00	Internal doors	£6,000.00	Internal doors	£6,000.00
	Floor finishes	£270.00	Floor finishes	£270.00	Floor finishes	£270.00	Floor finishes	£270.00
	Wall finishes	£3,312.00	Wall finishes	£3,312.00	Wall finishes	£3,312.00	Wall finishes	£3,312.00
	Ceiling finishes	£993.60	Ceiling finishes	£993.60	Ceiling finishes	£993.60	Ceiling finishes	£993.60
	Kitchen & Utility F&F	£8,250.00	Kitchen & Utility F&F	£8,250.00	Kitchen & Utility F&F	£8,250.00	Kitchen & Utility F&F	£8,250.00
	Bath & Wet Room F&F	£3,500.00	Bath & Wet Room F&F	£3,500.00	Bath & Wet Room F&F	£3,500.00	Bath & Wet Room F&F	£3,500.00
		£22,865.60		£22,865.60		£22,865.60		£22,865.60
M&E	General electrical circuit	£6,500.00	General electrical circuit	£6,500.00	General electrical circuit	£6,500.00	General electrical circuit	£6,500.00
	ASHP w/ cylinder	£12,000.00	ASHP w/ cylinder	£12,000.00	ASHP w/ cylinder	£12,000.00	ASHP w/ cylinder	£12,000.00
	Zehnder MVHR units	£4,000.00	Zehnder MVHR units	£4,000.00	Zehnder MVHR units	£4,000.00	Zehnder MVHR units	£4,000.00
	PV panels (18 per unit)	£10,800.00	PV panels (18 per unit)	£10,800.00	PV panels (18 per unit)	£10,800.00	PV panels (18 per unit)	£10,800.00
	12% saving vs. AD L	£33,300.00	12% saving vs. AD L	£33,300.00	12% saving vs. AD L	£33,300.00	12% saving vs. AD L	£33,300.00
Preliminaries		£22,093.87		£23,267.00		£24,028.25		£24,806.37
TOTAL	2% saving vs. AD L	£198,844.86	2% saving vs. AD L	£209,402.99	2% saving vs. AD L	£216,254.24	2% saving vs. AD L	£223,257.36

HT 641 LETI cost analysis headlines

- Window cost difference negligible
- MVHR adds capital uplift but also improves operational performance, reducing heating demand and EUI
- ASHP reduce from 7 kW to 3.5 kW due to reduced space heating demand
- Lower EUI enables PV provision to reduce 30% and achieve Net Zero
- Small capital cost savings realised
- Operational costs decrease c. 35%

Critical components of the structure and thermal envelope highlighted in green are essential to achieving the necessary fabric u-values. As previous commentary there is no difference between the fabric (except windows) for the two operational scenarios.

Windows have been upgraded from double to triple glazing for this scenario, costing an extra c. £625.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue.

While installing MVHR presents a capital cost uplift versus MEV it contributes to reducing space heating demand and EUI. Associated additional costs must be considered against the cost savings realised with these operational improvements: reduced ASHP costs changing from 7 kW to 3.5 kW units, 7 fewer photovoltaic panels per dwelling and greatly reduced operational costs for occupants.

Overall there is a c. 2% capital cost saving to upgrade AD: L (Wales) 2025 to the LETI operational scenario while running costs decrease c. 35%.

Section 4: Conclusions

4.1 Conclusions

High performance buildings are achievable without significantly altering the anticipated fabric specification of Building Regulations Wales 2025. Uplifts beyond basic compliance are limited to improved airtightness, mitigation of thermal bridges, improved quality of windows and provision of MVHR for ventilation.

Improved levels of building performance result in an inherently lower need for heat generation and on-site renewables, reducing the number of photovoltaics required to balance EUI and heating infrastructure size. These cost savings may mean the most economical way to achieve Net Zero is by leveraging the highest feasible level of performance and marketing this as a positive sales feature to realise higher property values and improve loan affordability, expanding the market.

In the case of larger or otherwise optimised buildings targeting heating demand or EUI based performance metrics could justify potential reductions in insulation thicknesses with the resulting material efficiencies benefitting embodied emissions and project costs.

Choice of construction methodology can significantly impact embodied emissions. The principle of replacing mineral and petrochemical-based materials with short-rotation biogenic alternatives lowers embodied emissions while increasing sequestration potential. Cost increases associated with lower carbon materials might be justified by leveraging additional value from the green credentials of the development; widespread adoption would reduce current premiums and offer an opportunity to re-establish a local resource market.

This assessment has focused on a range of residential typologies modelled on a nominal site at 50m altitude, applying typical design responses in an East-West orientation to demonstrate the technical feasibility of Net Zero. Further optimisations - including but not limited to improved form factor, orientation and fenestration design - could reach Net Zero more efficiently, driving further reductions in embodied carbon and realising cost savings for the construction.

Headlines for operational analysis

- Heating demand reductions > 80% achievable between identical buildings by improving airtightness & thermal bridging complemented by MVHR
- EUI & CO_2e reductions of 30-40% available applying these improvements
- Reduced EUI requires 30-40% fewer PV panels to achieve Net Zero balance
- Heat pumps reduce energy required for heating & hot water demand to < 25% of the direct electric equivalent

Headlines for embodied analysis

- Higher-density building typologies can facilitate material efficiencies that result in lower embodied carbon
- Changing from masonry construction to timber frame reduces CO_2e 20-30%
- Timber frame with biogenic insulants can sequester 3-5x CO_2e as equivalent built in masonry with PIR insulation
- Improved form factor can achieve high performance standards with less insulation, saving embodied carbon

HT 211 to AD L	Scenario 1: Masonry	Scenario 2: Framed	Scenario 3: Timber	Scenario 4: Timber Opt.
TOTAL	£844,416.68	£908,656.99	£961,250.74	£977,259.49
Cost per unit	£93,824.08	£100,961.89	£106,805.64	£108,584.39
Cost per m²	£1,568.09	£1,687.39	£1,785.05	£1,814.78

HT 421 to AD L	Scenario 1: Masonry	Scenario 2: Framed	Scenario 3: Timber	Scenario 4: Timber Opt.
TOTAL	£305,921.81	£327,789.00	£343,015.88	£353,433.38
Cost per unit	£152,960.91	£163,894.50	£171,507.94	£132,957.70
Cost per m²	£1,838.47	£1,969.89	£2,061.39	£2,124.00

HT 641 to AD L	Scenario 1: Masonry	Scenario 2: Framed	Scenario 3: Timber	Scenario 4: Timber Opt.
TOTAL	£203,093.28	£213,651.41	£220,502.66	£227,505.78
Cost per unit	£203,093.28	£213,651.41	£220,502.66	£227,505.78
Cost per m²	£1,839.61	£1,935.25	£1,997.31	£2,060.74

AD L (Wales) 2025 cost difference from LETI	HT 211	HT 421	HT 641
TOTAL	+ £15,440.58	- £3,834.28	- £4,248.42
Cost per unit	+ £1,715.62	- £1,917.14	- £4,248.42
Cost per m² of GIA	+ £28.67	- £23.04	- £38.48

Headlines for cost analysis

- Reducing embodied carbon 20-30% attracts a 5-16% uplift in capital cost
- Masonry construction costs least but is the most carbon intensive option, failing to achieve RIBA/ RIAI 2030 and LETI 2030 targets for most typologies
- Less efficient operational scenarios that omit MVHR (and/ or ASHP) can cost more to achieve Net Zero due to larger PV arrays and heating systems
- External finishes can have significant impact on project costs and embodied carbon - but do not contribute directly to building performance
- Using high quality local materials for external finishes can leverage higher value and increased property prices
- Energy efficiency is recognised as contributing to desirability, increased and market-resilient property prices

Section 5: Appendices

5.1 Building Typologies

5.1.1 Residential

Refer to drawings:

2740-211(02)100 - HT 211 Notional Site Layout
2740-211(02)101 - HT 211 Notional Street Elevation
2740-211(02)200 - HT 211 GF Plan
2740-211(02)201 - HT 211 1F Plan
2740-211(02)202 - HT 211 2F Plan
2740-211(02)300 - HT 211 Elevations
2740-211(02)301 - HT 211 Elevations

2740-421(02)100 - HT 421 Notional Site Layout
2740-421(02)200 - HT 421 Floor Plans
2740-421(02)300 - HT 421 Elevations

2740-621(02)100 - HT 641 Notional Site Layout
2740-621(02)200 - HT 641 Floor Plans
2740-621(02)300 - HT 641 Elevations

spring
design

Unit 2
Chapel Barns
Merthyr Mawr
Bridgend
CF32 0LS

T: 01656 656267
W: www.spring-consultancy.co.uk

Architecture
Low Energy Consultancy
Civil Engineering
Structural Engineering
Urban Design

Vale of Glamorgan Council

Net Zero Carbon Buildings Feasibility Study and Cost Assessment

Work Stages 4G - I

Evidence, Cost Implications & Scrutiny Skillset

March 2025

Revision: A

Architecture
Low Energy Consultancy
Civil Engineering
Structural Engineering
Urban Design

Contents

Section 1: Introduction

1.1 Introduction

Spring Design Consultancy Limited is appointed to assist Vale of Glamorgan Council in developing suitably evidenced Net Zero policy to guide, assess and determine applications for new-build residential and non-residential development within the emerging Replacement Local Development Plan 2021-2036.

This process has been divided into distinct work stages:

Work Stage 1	A - Policy Review B - Policy Approach C - Evidence Base
Work Stage 2	D - Methodologies E - Technical Feasibility
Work Stage 3	F - Cost Analysis
Work Stage 4	G - Evidence H - Cost Implications I - Scrutiny Skillset
Work Stage 5	Examination

This Work Stage 4G - I Evidence, Cost Implications & Scrutiny Skillset introduces the proposed policies and assesses the information required for submission to satisfy the required standards. Discussion follows to address the cost implications of these analyses and the skillset(s) required to scrutinise the information by Vale of Glamorgan officers.

Section 2: Deposit Plan Policy

2.1 Operational Net Zero

CC1: Residential Operational Net Zero Carbon Development

Proposals for one or more new dwellings will be required to achieve net-zero carbon operational emissions by:

A. Following the principles of the Energy Hierarchy for Planning, prioritising a reduction in energy demand and improved energy efficiency.

B. Achieving the following standards in individual dwellings as calculated using an identified energy performance model: :

From RLDP adoption to 31st March 2030

i. Space heating demand less than or equal to 40kWh/m²/year;

ii. Energy use intensity less than or equal to 75kWh/m²/year; and

From 1st April 2030 onwards

i. Space heating demand less than or equal to 15kWh/m²/year;

ii. Energy use intensity less than or equal to 40kWh/m²/year; and

C. Providing on-site renewable electricity generation with an output equivalent to at least the annual energy consumption of the development, as calculated using an identified energy performance model.

Where the use of onsite renewable energy generation to match total energy consumption is demonstrated to not be technically feasible the following hierarchy should be followed:

- renewable energy generation should be maximised as much as possible; and/or
- connection made to an existing or proposed low carbon district energy network (in compliance with Policy CC5);
- or where this is not possible the residual energy (the amount by which total energy demand exceeds the renewable energy generation) is to be offset by a contribution to the Council's Project Zero fund as far as economic viability allows.

Compliance must be evidenced within an Energy Report.

6.1 In response to the climate emergency declared in the Vale of Glamorgan, the RLDP sets policy that exceeds current Building Regulations and will deliver homes that are net zero in operation. The approach to delivering this should accord with the Energy Hierarchy for Planning, which requires the improvement of fabric standards, energy efficiency and minimising space heating requirements, before installing renewable energy and then offsetting residual energy if required. This is the most sustainable approach, and will also make an important contribution to addressing fuel poverty and improving social equity.

6.2 In order to comply with the policy, each dwelling will need to meet two metrics. The first is 'space heating demand,' which is the amount of heat energy needed to heat a home or building over a year and is expressed in kWh/m2/year. It is a measure of the thermal efficiency of the building and its latent requirement to consume heat energy before the in- or efficiency of the heating system is applied. The second metric is Energy Use Intensity (EUI), which measures all energy consumed by a building, calculated by dividing the total energy consumption of the building by its floorspace.

6.3 A phased approach is identified for the targets for space heating demand and energy use intensity to allow the development industry to upskill and for supply chains to respond to the policy direction. The maximum targets in the period up to 1st April 2030 are equivalent to the AECB CarbonLite New Build Standard (space heating demand less than or equal to 40kWh/m2/year and EUI of less than or equal to 75kWh/m2/year) and are also reflective of the Tai Ar Y Cyd net zero building baseline standard, which the Vale of Glamorgan Council and a number of RSLs have signed up to as a minimum standard for the delivery of net zero affordable homes in Wales.

6.4 The space heating demand and EUI targets will become more stringent for applications for new dwellings validated from 1st April 2030. At this point, new dwellings will need to meet Low Energy Transformation Initiative (LETI) standards (space heating demand less than or equal to 15kWh/m2/year and EUI of less than or equal to 40kWh/m2/year).

6.5 The policy will apply to all applications for new build dwellings, but not conversions.

6.6 In order to determine compliance with the policy, operational energy use must be calculated using a suitable energy performance model endorsed by RICS within the latest version of Whole Life Carbon Assessment for the Built Environment. Further detail on this will be contained with supporting Net Zero Buildings Supplementary Planning Guidance.

6.7 New buildings should contribute to the significant increase in renewable energy generation required between now and 2050. The most robust way to deliver the overall objective to balance total energy use and total renewable energy generation is for new developments to seek to achieve this balance at the site level. This also has the advantage of generating 'free' electricity close to its point of use, helping to deliver significant energy cost savings for residents and building occupiers. Solar PVs are one of the most effective means of generating onsite renewable energy. When combined with battery energy storage systems, solar PVs can also reduce peak demand on the electricity grid, by allowing energy to be stored and released when demand is highest.

6.8 In accordance with Criterion C, there may be some circumstances where it is not technically feasible to generate sufficient energy to offset the energy consumption. This may be the case in certain flatted developments with limited roof space. Where it has been robustly demonstrated that it is not possible to provide a policy compliant level of renewable energy on site, it will be necessary to offset this thorough an appropriate contribution to the Council's Project Zero Fund in order to fund other appropriate decarbonisation activities. Further details will be provided in the Supplementary Planning Guidance

2.2 Embodied Carbon

CC2: Embodied Carbon

Proposals for new residential development will be required to include an embodied carbon assessment, submitted as part of the Energy Report using a nationally recognised embodied carbon assessment methodology, and demonstrate actions taken to reduce whole life-cycle carbon emissions.

Between the adoption of the RLDP and 31st March 2030, new residential development will be expected to achieve an embodied carbon figure of less than or equal to 800 $kgCO_2e/m^2$ per dwelling.

After 1st April 2030, new residential development will be expected to achieve an embodied carbon figure of less than or equal to 600 $kgCO_2e/m^2$ per dwelling.

Where it is evidenced that it would not be viable to meet these targets for embodied carbon, a full justification will be required as part of the embodied carbon assessment within the Energy Report.

6.9 Embodied carbon is the carbon dioxide equivalent (CO_2e) emissions associated with materials and construction processes throughout the whole lifecycle of a building. To achieve climate targets, embodied carbon must be significantly reduced throughout the building life cycle.

6.10 As is the case with Policy CC1, a phased approach to embodied carbon reduction is set out. Applications validated prior to 1st April 2030 will be required to achieve an embodied carbon figure of 800 $kgCO2e/m^2$ per dwelling or less. This accords with the Tai Ar Y Cyd baseline standard for embodied carbon. From 1st April 2030 the standard will be more stringent at a maximum of 600 $kgCO2e/m^2$ per dwelling.

6.11 The policy will apply to all new dwellings but will not apply to conversions.

CC3: Presumption Against Demolition

Proposals for the demolition and replacement of a standalone building will only be acceptable where it is demonstrated that:

A. the building proposed for demolition is structurally unsound to the extent that it is not practical or viable to be repaired, refurbished, re-used, or re-purposed; or
B. there are significant public benefits which could not be delivered through repairing, refurbishing, re-using, or re-purposing; or
C. repairing, refurbishing, re-using, or re-purposing the building would likely result in equal or higher newly generated embodied carbon than if the building is demolished and a new building is constructed; or
D. repairing, refurbishing, re-using, or re-purposing the building would create a building with such poor thermal efficiency that on a whole life cycle basis would mean a lower net carbon solution would arise from demolition and re-build.

Compliance with Criteria A and B should be justified within a Demolition Statement. Compliance with Criteria C and D should be justified within the site's Energy Report.

Where demolition is justified replacement development should recover and reuse waste material from the demolition on sites wherever possible.

6.12 To avoid the wastage of embodied carbon in existing buildings and avoid the creation of new embodied carbon in replacement buildings, there is a presumption in favour of repairing, refurbishing, re-using and re-purposing existing buildings over their demolition. Proposals that result in the demolition of a building (in whole or a significant part) should be accompanied by a full justification for the demolition. This policy applies to standalone buildings in their own right and not ancillary buildings within the curtilage of larger buildings, such as a detached garage.

6.13 A strong justification must be submitted in displaying compliance with Criterion A. This must include detailed information on the building's condition and evidenced claims that the building's condition would not be suitable. Compliance with Criterion B would only be achievable where there is significant justification for a development. For example, if a small disused building was sited in a highly sustainable location that if demolished would provide the opportunity for large scale regeneration or affordable housing development.

6.14 In evidencing compliance with Criterion C and D Whole Life Carbon Assessments (WLCA) that are calculated through nationally recognised WLCA methodologies should be submitted. These should compare the anticipated lifecycle carbon of the building to be replaced and the replacement building. Inherently, the replacement building should be low carbon. The policy applies when demolition is proposed for buildings of any proposed or existing use.

6.15 In order to limit carbon in sourcing materials, and follow circular economy principles, replacement buildings should reuse materials recovered from any demolition that is permitted.

Section 3: Tai ar y Cyd

3.1 Introduction

Tai ar y Cyd is a collaboration between social landlords seeking to develop a standardised pattern book for the next generation of high performing, timber constructed homes. Supported by Welsh Government, the pattern book is designed to be built to common performance specifications which will incrementally work towards achieving net zero carbon in operation and make a step change in reducing embodied carbon in construction.

Published in early 2025, the pattern book will be used by the member social landlords to build new affordable housing and help meet the demand for new homes. This will promote investment and build confidence in a sustainable and local supply chain that can increasingly use Welsh timber. This will in turn enable the growth of Welsh SMEs and the development and refinement of green skills to deliver better quality and, over time, contribute to reducing build costs.

A primary part of the collaboration has been designing, modelling and refining fifteen of the most commonly applied social housing typologies. This ensures the promoted operational and embodied standards are deliverable across the housing portfolio rather than limited to a small range of variants.

Tai ar y Cyd has the potential to provide a robust feedback loop, including pilot testing sites and industry feedback on the proposed limits. There is an opportunity to ensure continuous improvement and broader adoption. As data improves the standards applied through the project will evolve to remain aligned with the UK's updated carbon budgets.

Stride Treglown led the project and developed the architectural proposals. Arda Consulting provided sustainability consultancy and Hoare Lea supported the project with MEP design.

3.2 Project Partners

Social Housing Provider Member Organisations

Wrexham County Borough Council / Cyngor Bwrdeistref Sirol Wrecsam
Cardiff / Caerdydd
Coastal Housing Group
Cyngor Abertawe Swansea Council
Cyngor Sir Gâr Carmarthenshire County Council
united welsh
Caerphilly County Borough Council / Cyngor Bwrdeistref Sirol Caerffili
Merthyr Valleys Homes
Vale of Glamorgan / Bro Morgannwg
Cyngor sir ddinbych denbighshire County Council
Powys
Pembrokeshire County Council / Cyngor Sir Penfro
Cyngor Sir Ynys Môn Isle of Anglesey County Council
RHA
North Wales Housing / Tai Gogledd Cymru
MHA
Caredig People · Homes · Communities
Trivallis.
Tai Tarian
Cyngor Sir y Fflint Flintshire County Council
Cymoedd i'r Arfordir Valleys to Coast
ClwydAlyn
Cartrefi Conwy

Partner Organisations

woodknowledge Wales
Supply Chain Sustainability School
Cast
Design Commission for Wales / Comisiwn Dylunio Cymru
Passivhaus Trust The UK Passive House Organisation
Constructing Excellence Wales
tpas Tenant Engagement Experts
cwmpas
tai pawb

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3.3 Operational Energy Standards

Tai ar y Cyd adopts a two-tier approach to operational carbon by setting a Baseline Standard (aligning with AECB CarbonLite) while establishing that projects should aspire to the Enhanced Standard (Passivhaus Classic). This establishes rigorous yet achievable standards that promote and prioritise energy efficiency to be complemented by on-site renewable generation energy to achieve net zero.

As the project seeks to improve energy efficiency and reduce carbon emissions it applies the Passivhaus methodology. Space heating demand - as calculated in PHPP - is the primary metric complemented by EUI.

The Baseline Standard mirrors the requirements of the AECB Carbonlite New Building Standard. This uses the Passivhaus methodology and assesses the same criteria but applies a relaxed space heating demand <40 kWh/m²/yr and EUI threshold of <75 kWh/m²/yr.

The Enhanced Standard requires compliance with the certifiable criteria of Passivhaus Classic. Dwellings must therefore demonstrate a space heating demand <15 kWh/m²/yr or peak heating load <10 W/m²/yr. While Passivhaus criteria uses Primary Energy (PE) or Primary Energy Renewable (PER) the EUI threshold is <35 kWh/m²/yr.

Assessment must be undertaken in PHPP by suitably qualified professionals. This would include AECB Approved Modellers, Certified Passivhaus Consultants and Designers or consultants/ designers with demonstrable experience in the use of PHPP.

As Passivhaus methodology applies more rigorous assumptions to thermal modelling and requires more meticulous site check and quality assurance than SAP it is anticipated that both standards will significantly reduce the performance gap.

3.4 Embodied Carbon Standards

Tai ar y Cyd applies the RICS Whole Life Carbon Assessment (WLCA) framework which adopts an adapted form of the life cycle stages outlined in EN 15978 to comprehensively evaluate the carbon impact of built assets. Reporting standards were most recently clarified in Whole life carbon assessment for the built environment 2nd edition (2023).

The threshold for embodied carbon ((A1-A5, B1-B5 & C1-C4 excluding renewables) aligns with RIBA 2025 limit of <800 kgCO_2e/m². The RIBA 2030 embodied carbon target of <625 kgCO_2e/m² is established as the aspiration as the project moves beyond trial projects.

Tai ar y Cyd recognises WLC/EC metrics and targets have progressed during the project lifecycle, reflected most significantly with the collaborative piece resulting in the UK Net Zero Carbon Buildings Standard (2024). It is anticipated that targets/ thresholds and reporting standards will need to be kept under constant review to maintain pace with best practice.

Space heating demand
<40 kWh/m²/year
(Baseline backstop limit)

Space heating demand
<15 kWh/m²/year*
(Enhanced Aspirational target)

Energy Use Intensity (EUI)
<75 kWh/m²/yr
(Baseline Backstop limit)

Energy Use Intensity (EUI)
<35 kWh/m²/yr
(Aspirational target)

Embodied Carbon
<800 kgCO_2e/m²
(Baseline Backstop limit)

Embodied Carbon
<625 kgCO_2e/m²
(Aspirational target)

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Section 4: Evidence

4.1 Operational Energy Evidence

CC1: Residential Operational Net Zero Carbon Development will require applications for residential development to submit supporting documentation in the form of an Energy Report.

Critical metrics against which policy compliance must be measured are the space heating demand, energy use intensity and renewable generation potential of the proposed dwellings.

All assessment should be undertaken in accordance with the internationally recognised RICS methodology which is based on EN 15978 and endorsed by RIBA, LETI, CIBSE and IStructE. This WLCA standard provides a detailed methodology to enable consistent measurement and quantification of whole life carbon emissions, inclusive of all embodied and operational carbon throughout the whole life cycle of a building.

Whole life carbon assessment for the built environment 2nd edition (2023) requires operational energy use predictions to be completed by a suitably qualified professional using the guidance outlined either in CIBSE's TM54, NABERS, ASHRAE Standard 90.1 or using the Passivhaus Planning Package (PHPP).

Approved Document L 2021/ 2022 calculations using the current SAP methodology are explicitly forbidden: these are not considered to be either an appropriate or accurate prediction of energy consumption. As limited details are available regarding the Home Energy Model (HEM), the proposed replacement for SAP under the Future Homes Standard, it cannot be established whether this tool will be considered suitable for modelling operational energy.

To facilitate scrutiny of reported figures against policy aspirations it is recommended the Energy Report also incorporates a range of supporting information. As a minimum this would include a Notional Specification, gross internal floor area, treated floor area, annual energy usage, heat loss form factor, glazed area and overheating risk.

Critical Metrics

- Space heating demand
- Energy use intensity (EUI)
- Renewable generation potential

Supplementary Information

- Notional specification
- Gross internal area (GIA)
- Treated floor area (TFA)
- Annual energy usage
- Heat loss form factor
- Glazed area
- Overheating risk

The Notional Specification should identify all planning stage assumptions informing the energy model regarding building fabric and heating, hot water and ventilation strategies. Compliance with the space heating demand will require meeting minimum fabric standards (air permeability and u-values) and integrating ventilation strategies (MVHR in most cases) that can be readily checked. EUI targets are likely to require the use of heat pumps in all but the most efficient of buildings and this can be checked within the provided information.

Gross internal area (GIA) is checked and reported by the design team throughout the design process as it directly impacts construction costs. Treated floor area (TFA) is a more nuanced area measurement required by Passivhaus methodology that excludes certain areas such as stairs. GIA should always exceed TFA.

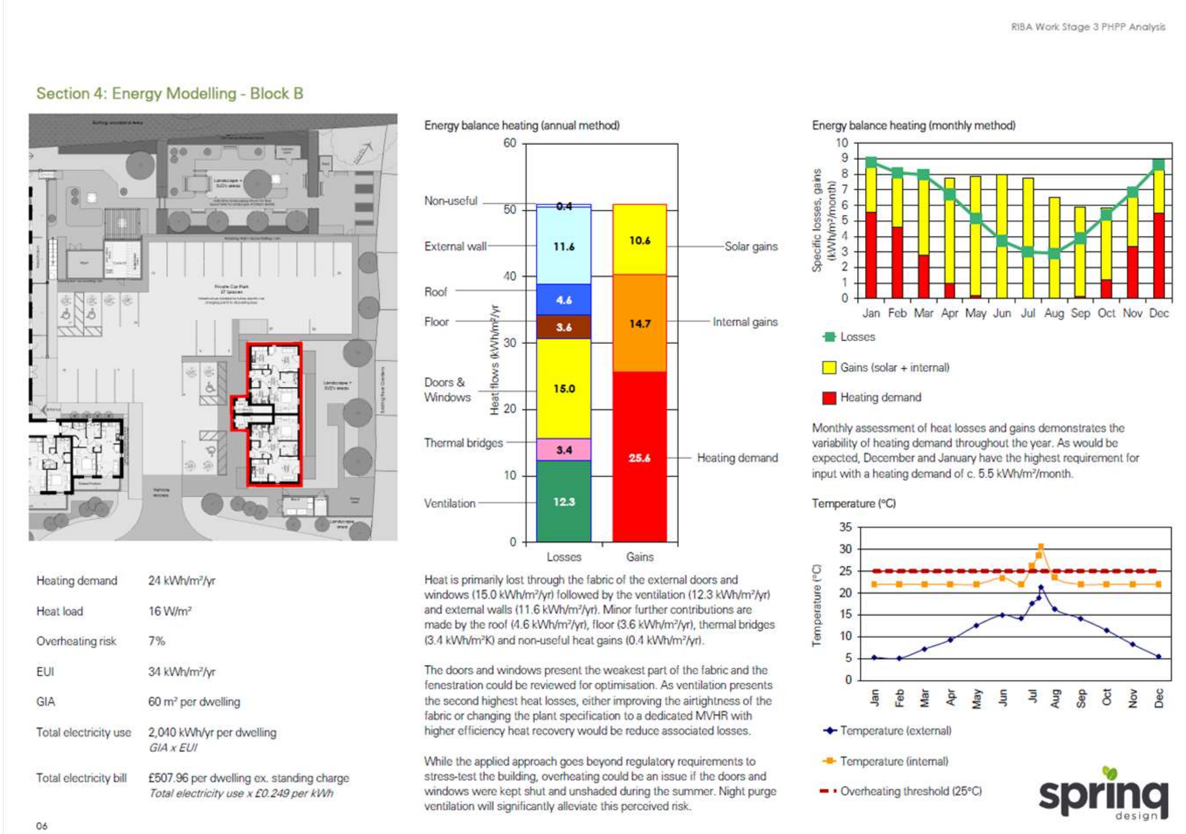

Fig. 01: Example of the presentation of technical ouputs for a residential block that enables scrutiny of the reported figures. This should be supplemented with a Notional Specification to clarify the applied assumptions.

Annual energy usage should be approximately the result of EUI x GIA and can be used to check the consistently of calculations. It is also essential to ensure the correct provision of on-site renewable energy generation to meet Net Zero.

Heat loss form factor expresses the relationship between the external heat loss area and internal floor area of a building, typically in the range of 0.5 to 5.0. A smaller number represents a more thermally efficient building that can achieve a higher standard of energy efficiency (i.e. lower space heating demand) than if the same Notional Specification were applied to a building with a higher heat loss form factor.

Glazed area compared to GIA will quickly establish if the building is overglazed (>20%) which will also be reflected in an unacceptable overheating risk (>10%).

Both critical metrics and supplementary information should be summarised in tables to expedite validation checks. Certain aspects could be supported by graphical outputs to provide more evidence for technical scrutiny: heat balance graphs would be one example of such an illustration, clearly identifying where heat loss occurs (e.g. walls, floors, windows, ventilation, etc.) and how this is balanced by heat gains (solar gains, internal gains and heating demand).

Appendix 7.2 Operational Evidence Examples demonstrates some precedents for how this information could be presented.

4.2 Embodied Carbon Evidence

CC2: Embodied Carbon and CC3: Presumption Against Demolition (C & D) will both require applications for residential development to submit supporting documentation in the form of an Energy Report. The additional information required to satisfy CC3 A & B within a Demolition Report are not considered within this commentary.

All whole life cycle and embodied carbon assessments should follow the internationally recognised RICS methodology based on EN 15978. This standard is endorsed by RIBA, LETI, CIBSE and IStructE and provides a detailed methodology to enable consistent measurement and quantification of whole life carbon emissions throughout the life cycle of buildings.

Whole life carbon assessment for the built environment 2nd edition (2023) defines how embodied carbon must be calculated. WLCA tools aligned with these reporting standards include Cerclos eTool, One Click LCA and the PHPP plug-in PHribbon.

CC2: Embodied Carbon requires the embodied carbon of development to be calculated excluding operational energy, water and user carbon. Critical metrics are therefore only embodied carbon (A1-5, B1-5, C1-4) and biogenic - sequestered - carbon (A1-5, B1-5, C1-4) which must be reported separately.

CC3: Presumption Against Demolition requires whole life carbon of development to be calculated including operational energy, water and user carbon. The critical metrics are therefore embodied carbon (A1-5, B1-5, C1-4), operational carbon (B6-7), user carbon (B8) and biogenic carbon (A1-5, B1-5, C1-4) which must again be reported separately.

To facilitate scrutiny of reported figures, supporting information could be requested. As a minimum this would include a Notional Specification and a breakdown of the calculated carbon emissions by life cycle stage: at each stage, emissions could be further broken down by building element.

Critical Metrics

- Embodied carbon (A1-5, B1-5, C1-4)
- Biogenic carbon (A1-5, B1-5, C1-4)

Supplementary Information

- Notional specification
- Upfront carbon (A1-5)
- Upfront biogenic carbon (A1-5)
- In use carbon (B1-5)
- Operational carbon (B6-8) - CC3 only
- In use biogenic carbon (B1-5)
- End of life carbon (C1-4)
- End of life biogenic carbon (C1-4)

A Notional Specification should identify all planning stage assumptions informing the carbon calculations. This would include preliminary assumptions about foundation types, constructional methodologies for all building elements - internal linings, structure, insulation and external finishes - and the applicable mechanical plant. It is acknowledged this is unlikely to reflect a resolved technical specification at point of planning submission: however, applicants developing more detailed proposals would benefit from being able to identify and apply lower carbon solutions in a replicable manner across development proposals.

Compliance with CC3 will require a minimum of two Notional Specifications to demonstrate what retrofit measures were considered for the existing and what constructions are proposed for the replacement building to achieve lower life cycle emissions.

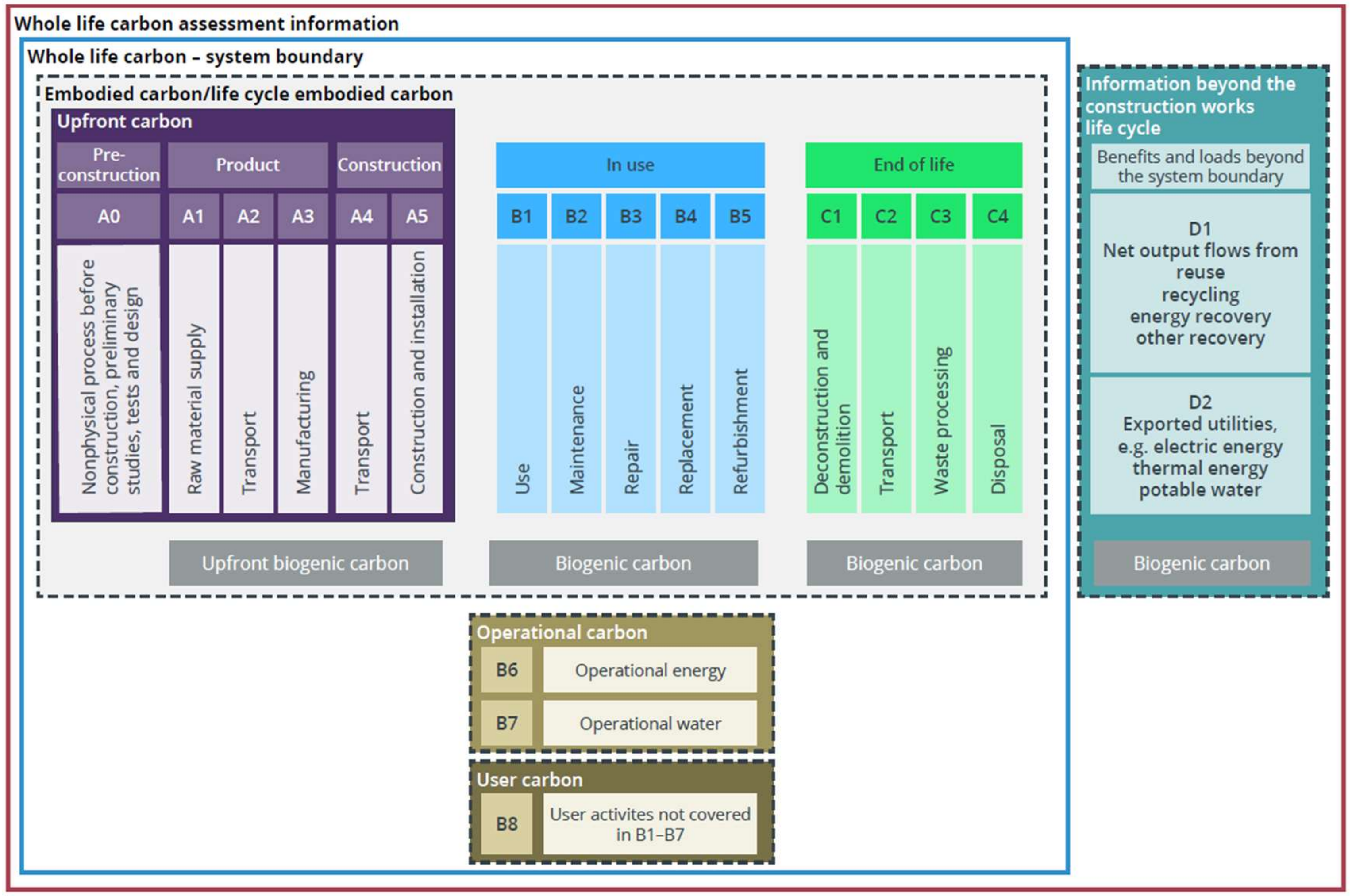

Fig. 02: Building life cycle stages and information modules with additions to illustrate sequestered biogenic carbon. RICS Whole life carbon assessment for the built environment 2nd edition (2023)

A breakdown of embodied and biogenic carbon by life cycle stage allows for comparison of upfront, in use and end of life emissions and where biogenic carbon is anticipated to be sequestered by the fabric of the building. Similarly, separating the emissions by building element facilitates more detailed scrutiny of what is contributing most significantly to life cycle emissions and should be used within the design process to drive a better informed specification.

Both critical metrics and supplementary information could be summarised in tables to expedite validation checks. Certain aspects could also be interpreted and presented graphically to improve legibility of the data.

Appendix 7.3 Embodied Evidence Examples demonstrates some precedents for how this information could be presented.

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Section 5: Cost Implications

5.1 Operational Energy Assessment Costs

A growing number of professional consultancies are equipped to undertake RICS aligned operational energy calculations for residential developments. Architectural practices are among those upskilling to develop the technical expertise and offer energy consultancy in-house as an extension of their design services.

Alternatively, where designers do not offer this service or developers desire comparative costings, external consultants can be appointed to undertake the energy assessment. Procurement of services via an additional consultant generally results in higher professional fees but this may be offset if the Energy Consultant is not VAT registered.

TM 54 Evaluating operational energy use at the design stage (2022) and ASHRAE 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings (2016) should be undertaken by suitably qualified individuals, typically CIBSE Chartered Engineers. CIBSE have a database of members on their website through which appropriately qualified individuals can be identified.

PHPP modelling should be undertaken by suitably qualified or demonstrably experienced individuals. This could be summarised as AECB Approved Modellers, Certified Passivhaus Consultants/ Designers or those who can evidence recent involvement in certified Passivhaus projects. Directories of appropriately qualified individuals are available through the websites of the Association for Environment Conscious Building (AECB), Passivhaus Trust and Passive House Institute.

There are 70+ Passivhaus Consultants/ Designers in Wales and hundreds more just across the border.

Residential developments of 10-50 dwellings typically attract a cost of £100-500 per unit ex. VAT assessed to a uniform specification. The variation in costings reflects how the energy consultancy is procured, the size and complexity of the design proposals and whether standard house types are applied across the project. Developers could expect to negotiate lower per unit rates for more significant developments of 50 or more dwellings that apply a uniform specification in tandem with standard house types.

Small developments of 10 or fewer dwellings and single family homes lack the replicability of larger assessments, therefore consultancy costs are likely to increase per unit. The most cost-effective way of procuring services for these developments will be to appoint suitably qualified designers who can conduct the assessment as an extension of their services.

Social housing delivered in the Vale of Glamorgan through the life of the rLDP should apply Tai ar y Cyd as a minimum standard for the partner organisations identified in 3.2 Project Partners. As this mandates minimum operational energy performance standards the equivalent of CC1: Residential Operational Net Zero Carbon Development, assessed through PHPP, no additional modelling would be required and as such there should be little to no additional cost in complying with policy. Development with a mix of market and social housing should benefit from economies of scale as only sales units will add to the required modelling.

While this commentary focuses on the upfront cost of commissioning assessments the exercise can be cost beneficial for developers. Integrating the analysis into design development can inform optimisations to actively reduce CapEx, focusing investment where it can make the most difference to energy efficiency.

Similarly, energy efficient homes are yielding greater market values compared to less efficient equivalents. The Octopus Energy commissioned Zero Bills and House Price Premiums (2024) demonstrated a green premium of 10.1% for properties valued £150-300k and 7.1% for properties valued £300-500k, recognising the inherent value of energy savings to householders. Combined with lower interest rates offered by lenders such as Ecology Building Society, high performance homes have the potential to offer a more lucrative investment for developers.

5.2 Embodied Carbon Assessment Costs

A growing number of professional consultancies are equipped to undertake RICS aligned embodied and WLCA carbon calculations for dwellings. Architectural practices are among those upskilling to develop the technical expertise and offer this consultancy in-house as an extension of their design services.

Alternatively, where designers do not offer this service or developers desire comparative costings, external consultants can be appointed to undertake embodied and WLCA carbon assessment. Procurement of services via an additional consultant generally results in higher professional fees but this may be offset if the consultant is not VAT registered.

Whole life carbon assessment for the built environment 2nd edition (2023) defines how life cycle analysis must be conducted and clarifies the system boundaries to apply for embodied carbon calculations.

Traditionally WLCA has been considered a specialised work package undertaken by Sustainability Consultants as limited tools were available to assist with the process. However, multiple RICS-aligned WLCA tools have been developed and refined in recent years and include Cerclos eTool, One Click LCA and the PHPP plug-in Phribbon. The accessibility of these tools has contributed to expanding the number of consultancies offering whole life cycle assessments.

Cerclos eTool and One Click LCA both offer in-depth training in their softwares that is recognised with graduate certificates. This allows those commissioning WLCA to identify qualified users of the software.

PHribbon modelling should be undertaken by suitably qualified or demonstrably experienced individuals. This could be summarised as AECB PHribbon Endorsed Users, other graduates of the AECB training course or those with experience of using the software. A directory of AECB PHribbon Endorsed Users is currently being compiled on the Association for Environment Conscious Building (AECB) website.

There are 60+ LCA Consultants in Wales and hundreds more just across the border.

Costs for WLCA will vary significantly depending on the detail required by the relevant policy position.

CC2: Embodied Carbon requires assessment excluding operational emissions and can therefore be calculated on a typology basis irrespective of the operational performance of each individual household.

Residential developments applying uniform fabric and plant specifications might typically attract a cost of £500-2,000 per typology ex. VAT. The variation in costings reflects how the consultancy is procured and the size and complexity of the design proposals.

CC3: Presumption Against Demolition requires WLCA of both a retrofit scenario of the existing building(s) and replacement new build proposals. As operational carbon is expected to contribute significantly to life cycle emissions, typological assessment would have to be supplemented with converting operational energy performance for each residential block into emissions. While this represents slightly more work than an embodied carbon assessment, critical calculations will have been completed for CC1: Residential Operational Net Zero Carbon Development and should therefore add little cost beyond what has already been identified. Assessing the existing building will constitute a separate work package that will be bespoke to each site.

Tai ar y Cyd mandates maximum embodied carbon thresholds similar to those of CC2: Embodied Carbon. As such, no additional modelling would be required for social housing and there should be little to no additional cost in complying with policy. Development with a mix of market and social housing should benefit from economies of scale as only sales units will add to the required modelling.

Section 6: Scrutiny Skillset

6.1 Scrutiny Skillset

Providing Energy Reports are formatted to clearly present the required outputs for policy compliance, validation should be a straightforward exercise of comparing reported figures against the policy targets.

It is recognised that to scrutinise the reported figures in detail will require a more advanced understanding of building physics and life cycle assessment. While this is likely to require interested individuals within VoGC to train and upskill as 'Climate Champions' or for VoGC to use external consultants, general principles could be summarised in a guidance document for officers to enable them to identify spurious claims. This would limit the number of cases referred to the VoGC Climate Champion(s) or external consultants.

In addition to the Planning Team, VoGC could choose to involve colleagues from Building Control in the scrutiny process. Building Control Surveyors, soon to become Registered Building Control Approvers, must possess a technical understanding of building physics and should therefore require less training in this field.

VoGC could also choose to involve colleagues from the Education and Housing Development Teams who have established experience of delivering AECB CarbonLite, Passivhaus and Net Zero buildings.

Members of recognised professional associations will be subject to a code of conduct and ethics. Reports prepared by members of these organisations should be expected to uphold those professional standards and any deliberate infraction should be reported to the relevant professional body.

6.2 Embedded Climate Champion(s)

Developing in-house expertise in building physics and life cycle assessment would be one option for VoGC to consider. This could either be achieved by upskilling existing team members or hiring appropriately qualified individual(s) to supplement the existing team.

To develop the skills in-house will require identifying team members willing to train in these specialisms. Internal training has the benefit of broadening existing skillsets and empowering officers to have agency in determination of issues pertaining to the new policy.

This approach does have drawbacks, primarily that it requires at least one VoGC employee - ideally more to ensure no individual is over-resourced and there is some provision for holiday cover - engages with the subject material, undertakes relevant primary training and continues to supplement this with CPD to keep pace with industry and regulatory change. Upskilling in these twin fields represents a considerable learning curve and a significant ongoing commitment for VoGC to maintain and refine these skillsets.

Hiring additional team member(s) with the identified specialisms would be an option that circumvents the need for VoGC to fund primary training. This would embed a specialist within the team to develop the knowledge base of their fellow officers through both formal and informal training.

Unless multiple positions could be created it would, at least initially, require all queries on this matter to be referred to this individual.

It is acknowledged current departmental budgets are unlikely to have allocated any funds for recruitment in this field. As with developing the expertise with existing team members, ongoing CPD and training commitments would be the responsibility of VoGC.

6.3 Continuing Professional Development

Continuing Professional Development (CPD) would be integral to ensuring in-house expertise keeps pace with regulatory changes and continues to be refined. CPD encompasses both structured and unstructured learning - broadly translated as taught content and self-directed study or reading relevant publications - with the below commentary considering some options for structured learning.

Taught courses on the subjects of operational energy and embodied carbon - complemented by case studies, conferences, site visits and webinars - are available through Association for Environment Conscious Building (AECB), Coaction Training CIC, Green Register, Passivhaus Trust, Passive House Institute and international Passive House Association (iPHA). Most are recognised with formal qualifications to demonstrate competency, subject to successfully passing an exam on the subject matter.

Locally, Construction Wales Innovation Centre (CWIC) within the University of Wales Trinity Saint David in Swansea is facilitating training courses specifically targeting the reduction of operational energy.

The Centre for Alternative Technology (CAT) in Machynlleth has been a centre of innovation in low carbon construction for decades and contributed significantly to discourse on the subject, particularly with publications such as Zero Carbon Britain: Rethinking the Future (2013). In addition to hosting workshops and conferences it offers short courses and a range of graduate degrees,

Bespoke training could also be designed for VoGC in collaboration with suitably qualified consultancies or course providers. This would ensure the training was both tailored to account for current knowledge levels and addressed all areas of policy compliance.

6.4 External Consultancy

As already referenced, an alternative method would be to use external consultants to assist with verifying the accuracy of operational and embodied carbon reports.

A growing number of professional consultancies are equipped to undertake RICS aligned assessments for residential developments. Architectural practices are among those upskilling to develop the technical expertise to offer this consultancy in-house.

Databases of suitably qualified individuals are available to access via the relevant industry body as described within 5.1 Operational Energy Assessment Costs and 5.2 Embodied Carbon Assessment Costs.

While this approach may cost VoGC more per application than using an in-house Climate Champion it also removes the burden of ongoing training commitments and associated costs. Acknowledging reports from Local Authorities that planning teams are already overstretched, this would also circumvent the need to reallocate resource to these specialisms.

Section 7: Appendices

7.1 Glossary

7.1.1 Carbon Definitions

Clarity and consistency in the basic terminology used to discuss carbon and Net Zero is key to ensuring meaningful outcomes.

Carbon Definitions for the Built Environment, Buildings and Infrastructure: Improving Consistency in Whole Life Carbon Assessment and Reporting (2023) is a collaboration between professions throughout the construction industry including the Chartered Institute of Building Service Engineers (CIBSE), Institution of Civil Engineers (ICE), Institution of Structural Engineers (IStructE), Low Energy Transformation Initiative (LETI), Royal Institute of British Architects (RIBA), Royal Institute of Chartered Surveyors (RICS), UK Green Building Council and the Whole Life Carbon Network (WLCN) and applies the following.

Greenhouse Gases (GHG)
often 'carbon emissions' in general usage
'Greenhouse Gases' are constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds.

Whole Life Carbon
'Whole Life Carbon' emissions are the sum total of all asset related GHG emissions and removals, both operational and embodied over the life cycle of an asset including its disposal (Modules: A0-A5; B1-B7; B8 optional; C1-C4, all including biogenic carbon, with A0 assumed to be zero for buildings). Overall Whole Life Carbon asset performance includes separately reporting the potential benefits or loads from future energy or material recovery, reuse, and recycling and from exported utilities (Modules D1, D2).

Embodied Carbon *or* Life Cycle Embodied Carbon
'Embodied Carbon' emissions of an asset are the total GHG emissions and removals associated with materials and construction processes throughout the whole life cycle of an asset (Modules A0-A5, B1-B5, C1-C4, with A0 assumed to be zero for buildings).

Upfront Carbon - Buildings
'Upfront Carbon' emissions are the GHG emissions associated with materials and construction processes up to practical completion (Modules A0-A5). Upfront carbon excludes the biogenic carbon sequestered in the installed products at practical completion.

Operational Carbon - Energy, Buildings
'Operational Carbon - Energy' (Module B6) are the GHG emissions arising from all energy consumed by an asset in-use, over its life cycle.

Carbon Sequestration
'Carbon Sequestration' is the process by which carbon dioxide is removed from the atmosphere and stored within a material - e.g. stored as 'Biogenic Carbon' in 'Biomass' by plants/ trees through photosynthesis and other processes.

Biogenic Carbon
'Biogenic Carbon' refers to the carbon removals associated with carbon sequestration into biomass as well as any emissions associated with this sequestered carbon. Biogenic carbon must be reported separately if reporting only upfront carbon but should be included in the total if reporting embodied carbon or whole life carbon.

These definitions only address the GHGs with Global Warming Potential assigned by the Intergovernmental Panel on Climate Change (IPCC). A0 is generally assumed to be zero for buildings.

7.1.2 Net Zero Definitions

Net Zero (whole life) Carbon
A 'Net Zero (whole life) Carbon' Asset is one where the sum total of all asset related GHG emissions, both operational and embodied, over an asset's life cycle (Modules A0-A5, B1--B8, C1-C4) are minimized, which meets local carbon, energy and water targets or limits, and with residual 'offsets', equals zero.

To meet the requirements of 'Net Zero (whole life) Carbon' the definitions for 'Net Zero Upfront Carbon', Net Zero Embodied Carbon', 'Net Zero Capital Carbon', Net Zero operational Carbon - Energy', 'Net Zero Operational Carbon - Infrastructure', 'Net Zero In-Use Carbon Asset' and 'Net Zero Operational Carbon - Water' must also be individually met as applicable.

Net Zero Carbon Embodied Carbon *or*
Net Zero Life Cycle Embodied Carbon
A 'Net Zero Embodied Carbon' asset is one where the sum total of GHG emissions and removals over an asset's life cycle (Modules A0-A5, B1-B5 and C1-C4) are minimized, which meets local carbon targets or limits (e.g. $kgCO_2e/m^2$), and with additional 'offsets', equals zero.

Net Zero Upfront Carbon
A 'Net Zero Upfront Carbon' asset is where the sum of GHG emissions, excluding 'biogenic carbon', from Modules A0-A5 is minimized, which meets local carbon targets or limits (e.g. $kgCO_2e/m^2$), and with additional 'offsets', equals zero.

Net Zero Operational Carbon - Energy
A 'Net Zero Operational Carbon - Energy' asset is one where no fossil fuels are used, all energy use Module B6) has been minimized, meets the local energy use target or limit (e.g. $kWh/m^2/a$) and all energy use is generated on- or off- site using renewables that demonstrate additionality. Direct emissions from renewables and any upstream emissions are 'offset'.

Direct emissions must include CH_4 and N_2O emissions from the combustion of biomass and biodiesel fuels. Upstream emissions include: direct and indirect emissions from energy generation and distribution, WTT emissions for energy consumed in the building and from energy generation and distribution.

Net Zero Operational Carbon - Water
A 'Net Zero Operational Carbon - Water' asset is one where water use (Module B7) is minimized, meets local water targets or limits (e.g. litres/person/year) and where those GHG emissions arising from water supply and wastewater treatment are 'offset'.

Net Zero In-Use Asset
A 'Net Zero In-Use Carbon Asset' is one where on an annual basis the sum total of all asset related GHG emissions, both operational and embodied, (Modules B1-B8) are minimized, which meets local carbon, energy and water targets or limits, and with residual 'offsets', equals zero.

Additionality
Procurement of renewable energy for the asset's use which results in new installed renewable energy capacity that otherwise would not have occurred had the intervention not taken place.

Carbon Neutral
All carbon emissions are balanced with offsets based on carbon removals or avoided emissions.

Absolute Zero Carbon
Eliminating all carbon emissions without the use of credits.

7.1.3 Reference Terms

ASHP
Air source heat pump: heating and hot water from electrical source. Efficiency described by COP/ SCOP.

COP/ SCOP
(Seasonal) coefficient of performance: rate of conversion of electricity to useful heat energy.

MEV
Mechanical extract ventilation: constant mechanical extraction from 'wet' rooms (bathroom, kitchen, utility, WC, etc.) with fresh air from trickle vents circulated through the building by depressurisation.

MVHR
Mechanical ventilation with heat recovery: ventilation systems that ensure a constant throughput of fresh, filtered air. 'Waste' heat is transferred from outgoing exhaust air to incoming fresh air to pre-warm it and reduce heating demand.

CO_2e Emissions
Equivalent carbon dioxide emissions calculated using the global warming potential (GWP) of exhaust gases.

Form Factor
Expresses the relationship between the treated floor area and area of the thermal envelope. A better form factor signifies a more efficiently designed building.

Thermal Envelope
The insulated components (floors, walls, ceilings) that separate internal and external volumes. Note this often excludes features such as porches and balconies.

Treated Floor Area (TFA)
The floor area of the rooms within the building that are heated. It excludes areas of internal partitions, doors, stairs and unusable spaces.

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7.2 Operational Evidence Examples

7.2.1 Critical Metrics

The Energy Report should open by stating compliance against the critical metrics. The precedent opposite - while not intended for a project designed to comply with CC1: Residential Operational Net Zero Carbon Development - demonstrates how space heating demand, EUI and other information can be collated in a table for validation checks.

Additional commentary offers insight into the results and locates relevant supporting information within the body of the document.

RIBA Work Stage 3 PHPP Analysis

Section 2: Executive Summary

All plots were modelled within PHPP to calculate the annual heating demand. As the development pattern prioritises flatted typologies, models have been created to capture each accommodation block following the Passivhaus methodology.

As summarised in the adjacent table the dwellings achieve the heating demand threshold defined by the AECB CarbonLite Building Standard. This aligns with Welsh Government policy and the alternative method to EPC A outlined in WDQR 2021 in reducing the heating demand of dwellings. Significant improvement upon the 40 kWh/m²/yr standard is realised for Block A courtesy of the favourable ratio of internal volume to thermal envelope (form factor).

Plots 51-54 exceed the 3% best practice overheating risk with windows closed: as explained opposite, this goes beyond regulatory requirements (which would account for night purge ventilation) to stress-test building performance. In combination with the mandatory and more granular overheating assessment applied through TM59 Design methodology for the assessment of overheating risk in homes it can be assessed whether any mitigation measures are required.

Full outputs from the modelling exercise are presented and discussed for each building in Section 4. Energy Modelling.

Section 3. Notional Specification outlines the assumed values used to inform the PHPP modelling exercise. These values should be considered the minimum specification to be achieved to deliver this development and any alternative proposals must be tested within PHPP to establish its impact on the calculated energy performance.

As the discussion contained within Section 4. Energy Modelling, changes to the specified assumptions can significantly impact the energy balance which will directly influence the heating demand. It is therefore critical to carefully manage product substitutions within the tendering process to avoid diluting the energy efficiency aspirations.

Models representing more than one dwelling will not capture the granular detail of individual dwellings within a larger block as they aggregate the energy balance into a single output, e.g. outer units with larger extents of exposed surface area are likely to have a higher heating demand than inner units. Should individual assessment of typologies (i.e. external or internal units; bottom, middle or top floor) be required, Spring can undertake this as an additional work package.

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Blocks	GIA & TFA	Form Factor	Proposed Air Permeability at 50 Pa	Heating Demand	Heat Load	Energy Use Intensity (EUI)	Overheating	AECB CarbonLite Building Standard
Block A	3247m²	1.56	1.5 m³/m²/hr	10 kWh/m²/yr	9 W/m²	29 kWh/m²/yr	2%†	Y
Plots 1-50	2615m²							
Block B	255m²	3.35	1.5 m³/m²/hr	24 kWh/m²/yr	16 W/m²	34 kWh/m²/yr	7%†	Y
Plots 51-54	223m²							

† All dwellings are modelled without additional purge ventilation via windows through summer to demonstrate the worst-case scenario for overheating in current climatic conditions. This represents modelling beyond regulatory requirements which incorporate the effects of night purge ventilation to help cool dwellings: modelling could be augmented with opened windows and immediately reduce the calculated risk. Conversely, an additional summer temperature increase could be applied to test future climate scenarios and ensure climate resilience.

As flats, all dwellings will require additional assessment by TM59 Design methodology for the assessment of overheating risk in homes to demonstrate compliance with WDQR 2021.

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7.2.2 Notional Specification

This precedent identifies the minimum amount of information required for a Notional Specification. It could be embellished with significantly more detail and this will be required for embodied carbon calculations: refer to 7.3.2 Notional Specification.

RIBA Work Stage 3 PHPP Analysis

Section 3: Notional Specification

PHPP requires the input of a large body of data to populate the model to calculate the energy balance and heating demand. The Passivhaus methodology clearly defines this process to ensure consistent results.

Standard rates of occupancy have been applied for energy modelling.

The values presented should be considered the minimum standard to be achieved. Any alternative proposals must be scrutinised to ensure conformity with PHPP input (e.g. use of λ = 90/90 values for calculating u-values) and tested within the model to check there is no detrimental impact to the calculated heating demand.

Stated u-values must be calculated via Passivhaus methodology. This is distinct from SAP methodology and therefore produces different values. Similarly, psi-values are calculated to external dimensions for Passivhaus rather than internal dimensions for SAP. All junctions should therefore report to both methodologies to simplify PHPP and SAP calculations.

Excepting door and window installations, all thermal bridges have been assigned a psi-value of 0.050 W/mK. Door and window junctions have been assigned a psi-value of 0.040 W/mK. These psi-values should be surpassed by well-resolved architectural detailing, lowering heat loss and space heating demand further.

All information is presented for coordination to ensure alignment with the materials and products available within existing supply chains to safeguard project viability.

Factor	Limit	Units	Notes
Building Fabric			
External fabric u-values	floor/ soffit 0.110	W/m^2K	Appendix E threshold
	walls 0.135	W/m^2K	calculated from agreed 219mm stud construction
	roofs 0.110	W/m^2K	Appendix E threshold
Thermal bridges (ψ–value)	0.050	W/mK	see adjacent commentary
Air permeability	1.50	m^3 @ 50 Pa	AECB CarbonLite Building Standard threshold
Doors & Windows			
Frames U_f	0.98	W/m^2K	Idealcombi Futura+ & Futura+ I
Glazing U_g	1.00	W/m^2K	double low-E glazing 16mm Argon
	0.65	g-value	
Panel	0.52	W/m^2K	louvre panel
Window reveals	0.153	m	
Ventilation, Heating, DHW + Distribution			
Air supply rate	30	m^3/h per person	balanced mechanical ventilation
Compact EAHP	85.00	% heat recovery†	Pichler PKOM 4
	212	L	integral hot water cylinder
Supply & exhaust ducts	length TBC	m	measured individually for each flat
	diameter 0.150	m	
Ventilation duct insulation	0.050	m	assume non-reflective ArmaFlex closed cell insulation
	0.040	W/mK	
Heating strategy			heat delivered by supply air + towel radiators
Domestic hot water	55	°C	
HWT & pipe insulation	0.050	m	assume non-reflective ArmaFlex closed cell insulation
	0.040	W/mK	
Summer Ventilation			
Compact unit			summer bypass†
Windows			closed - see notes in **Section 2: Executive Summary**

† PKOM 4 is also able to provide active cooling, helping further secure the comfort of building occupants during future climate scenarios.

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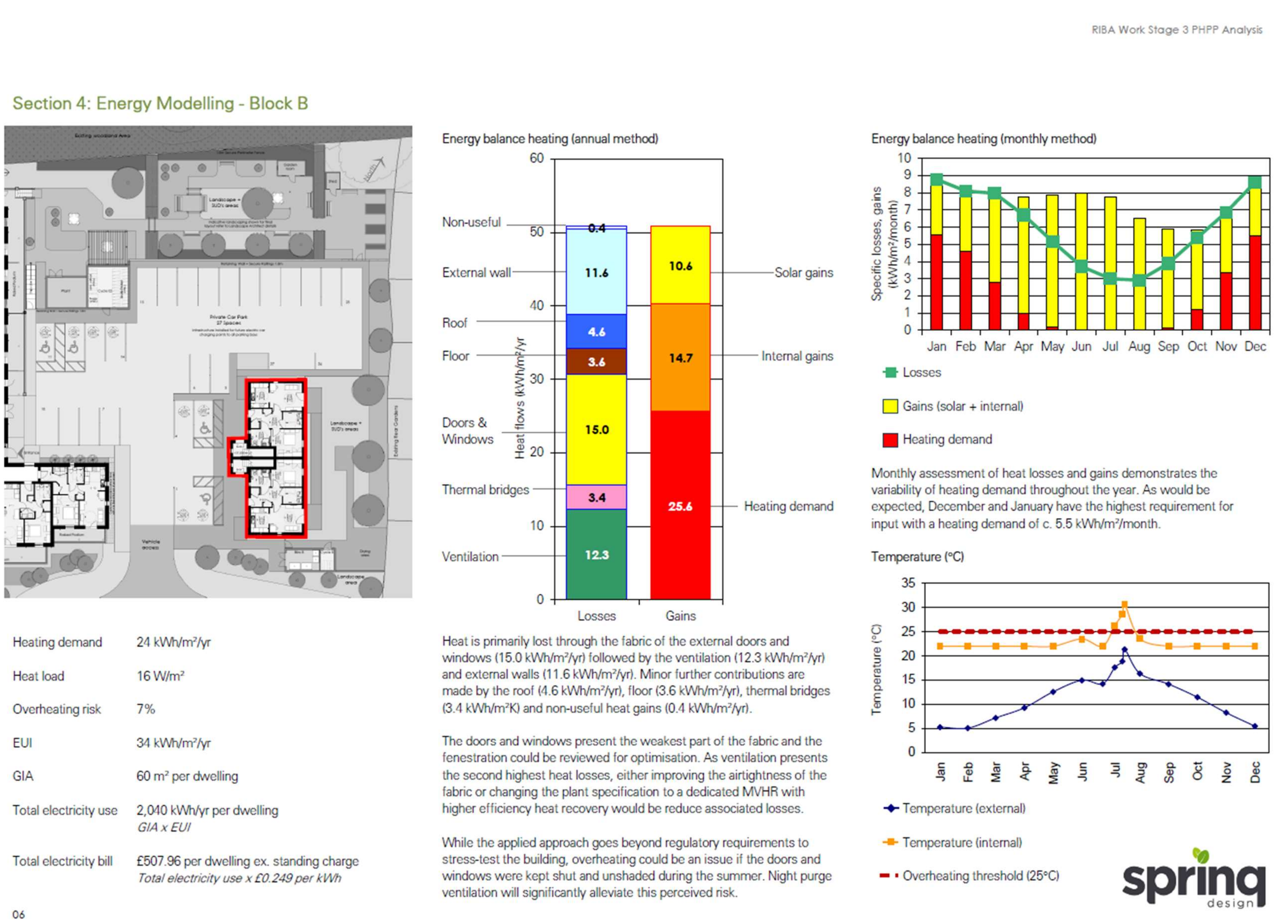
7.2.3 Supplementary Evidence

Modelling of each individual block could be presented as in the precedent opposite. Critical metrics are all addressed, supplemented by both annual and monthly energy balance graphs to demonstrate where heat losses and gains occur and an internal temperature graph to show the overheating risk.



RIBA Work Stage 3 PHPP Analysis

Section 4: Energy Modelling - Block B

Heating demand	24 kWh/m²/yr
Heat load	16 W/m²
Overheating risk	7%
EUI	34 kWh/m²/yr
GIA	60 m² per dwelling
Total electricity use	2,010 kWh/yr per dwelling *GIA x EUI*
Total electricity bill	£507.96 per dwelling ex. standing charge *Total electricity use x £0.249 per kWh*

Heat is primarily lost through the fabric of the external doors and windows (15.0 kWh/m²/yr) followed by the ventilation (12.3 kWh/m²/yr) and external walls (11.6 kWh/m²/yr). Minor further contributions are made by the roof (4.6 kWh/m²/yr), floor (3.6 kWh/m²/yr), thermal bridges (3.4 kWh/m²K) and non-useful heat gains (0.4 kWh/m²/yr).

The doors and windows present the weakest part of the fabric and the fenestration could be reviewed for optimisation. As ventilation presents the second highest heat losses, either improving the airtightness of the fabric or changing the plant specification to a dedicated MVHR with higher efficiency heat recovery would be reduce associated losses.

While the applied approach goes beyond regulatory requirements to stress-test the building, overheating could be an issue if the doors and windows were kept shut and unshaded during the summer. Night purge ventilation will significantly alleviate this perceived risk.

Monthly assessment of heat losses and gains demonstrates the variability of heating demand throughout the year. As would be expected, December and January have the highest requirement for input with a heating demand of c. 5.5 kWh/m²/month.

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7.3 Embodied Evidence Examples

7.3.1 Critical Metrics

The Energy Report should open by stating compliance against the critical metrics. The precedent opposite - while not intended for a project designed to comply with CC2: Embodied Carbon or CC3: Presumption Against Demolition - demonstrates how upfront, life cycle and sequestered carbon and other information can be collated in a table for validation checks.

Additional commentary offers insight into the assumptions and exclusions informing the calculations.

Results

Headline Figures

Table 1 gives the whole life embodied and operational carbon emissions for the full lifecycle (cradle to grave, stages A-C), with a 60 year reference study period.

Results are reported as net emissions, both as total tonnes of CO_2e released, and standardised to enable comparison with other buildings by dividing emissions by the Gross Internal Floor Area (GIA) ($kgCO_2e/m^2$ GIA)

Table 1. Headline figures for Parc y Rhodyn Passivhaus

Operational	Proposed dwelling	Target achieved
Space Heating kWh/m^2 TFA.a	15.3	Passivhaus
EUI kWh/m^2 GIA.a	82	RIBA: Business as Usual
Tonnes CO_2e over 60 yrs (inc. PV generation)	21.8	-
$kgCO_2e/m^2$ GIA over 60 yrs (inc. PV generation)	111	-
Embodied		
Full results, tonnes CO_2e A-C over 60 yrs	80.9	-
Full results, $kgCO_2e/m^2$ GIA over 60 yrs	413	-
Combined total tonnes, operational + embodied	02.7	-
Module D $kgCO_2e/m^2$ GIA	-69	-
Stored biogenic carbon, tonnes CO_2e	75.1	
LETI (excludes external works and PV)		
Lifecycle embodied carbon, $kgCO_2e/m^2$ GIA over 60 yrs	361	Band A (LETI 2030 Design Target)
Upfront embodied carbon, $kgCO_2e/m^2$ GIA over 60 yrs	305	Band B
RIBA (excludes external works)		
Lifecycle embodied carbon, $kgCO_2e/m^2$ GIA over 60 yrs	413	RIBA 2030 Target

Figure 1 shows the total tonnes of embodied and operational carbon emissions over a 60 yer reference lifespan. Figure 2 shows the cumulative, year-on-year combined embodied and operational carbon emissions.

The cumulative chart (Figure 2) shows net emissions - the chart begins below zero as it starts at the point of *net* A1-A5 emissions including sequestered carbon. The steps in the line indicate where products or materials are replaced. The large uptick at the end indicates end of life emissions, including the release of stored biogenic carbon. In reality, these emissions can be avoided if the

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building remains in use and intact beyond the 60 year reference lifespan. For whole life carbon assessment they must be accounted for, as the future of the building cannot be known.

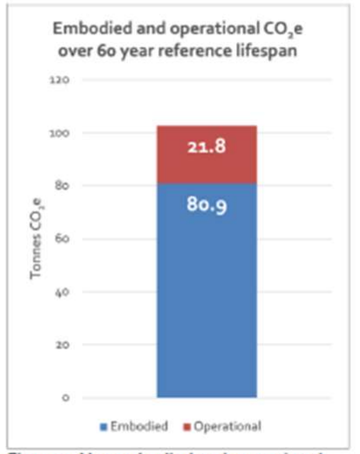

Figure 1. Net embodied and operational carbon

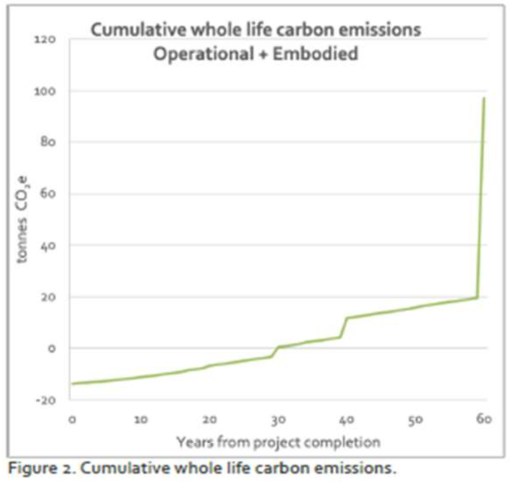

Figure 2. Cumulative whole life carbon emissions.

LETI Carbon rating

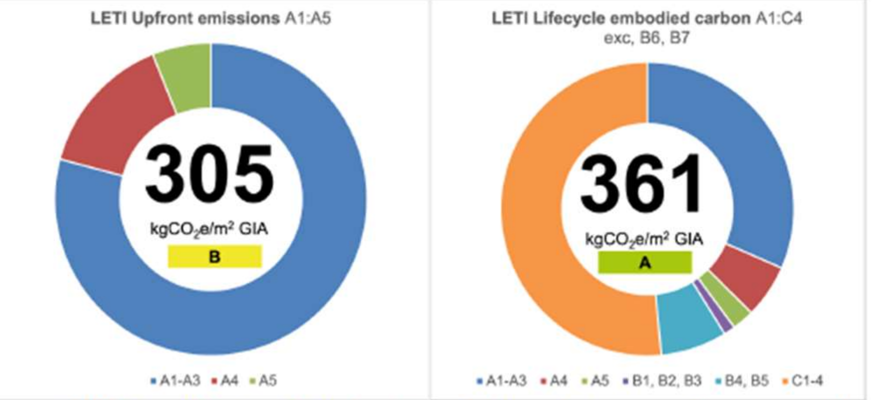

Figure 3. LETI Upfront and Lifecycle embodied carbon rating results. Colours indicate proportion of emissions assigned to each lifecycle stage

Figure 3 shows the results compared to the LETI ratings for Lifecycle and Upfront embodied carbon benchmarks (which range from A++ to G). Parc y Rhodyn achieves a B for Upfront carbon (those emissions caused by everything up to completion of the building) and an A for Lifecycle carbon (all embodied emissions over the whole lifecycle, including ultimate deconstruction).

The doughnut charts are split into the different lifecycle stages, indicating the proportion of emissions resulting from each lifecycle stage. For Upfront emission by far the greatest emissions are

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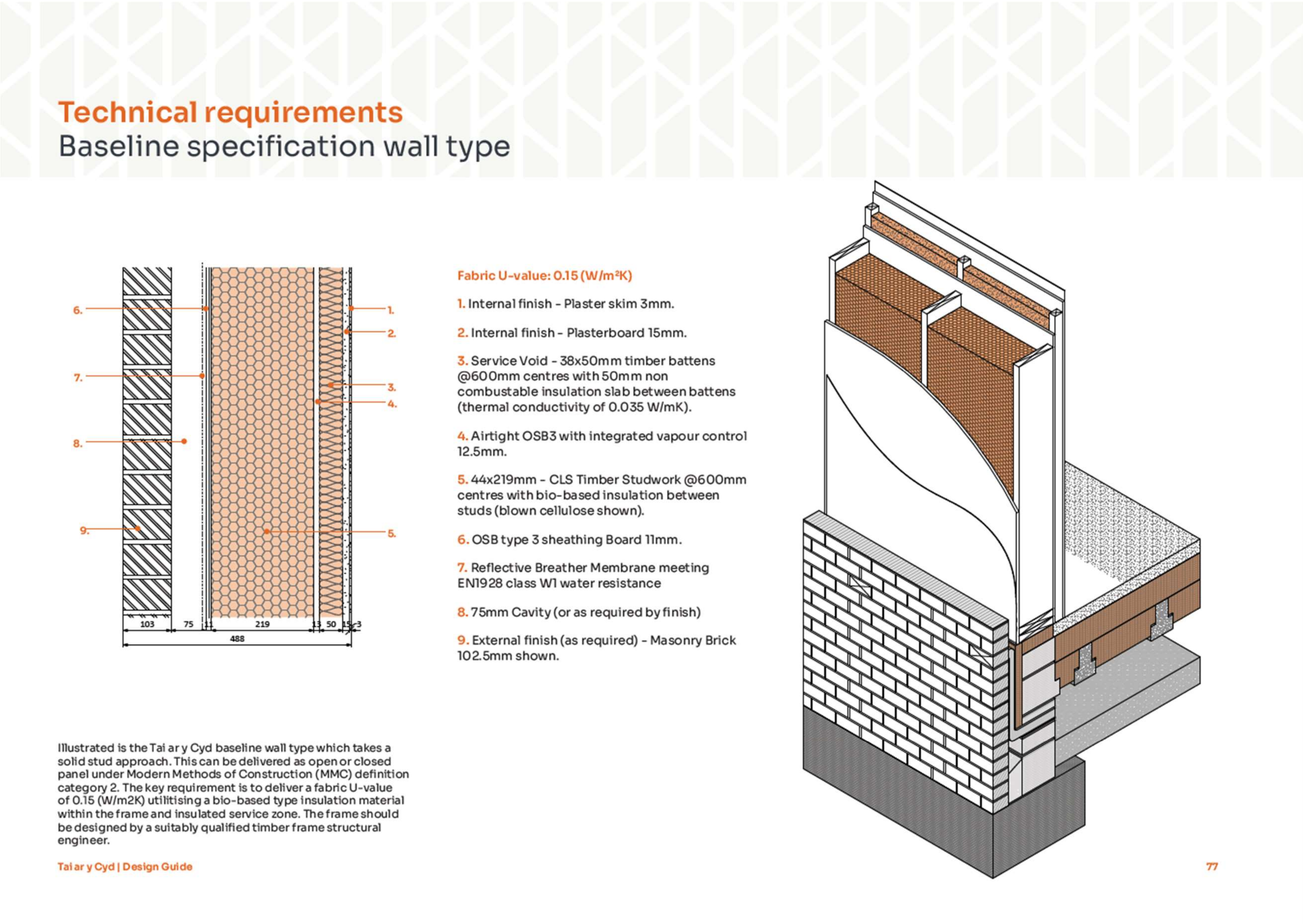
7.3.2 Notional Specification

While unusual to develop the detail of constructions to the extent of this precedent prior to planning, notional specifications will be essential to achieving embodied and life cycle carbon targets.

Proposals implementing Tai ar y Cyd will need to follow the defined construction methodologies, significantly simplifying the process for applicants.



Technical requirements
Baseline specification wall type

Fabric U-value: 0.15 (W/m²K)

1. Internal finish - Plaster skim 3mm.
2. Internal finish - Plasterboard 15mm.
3. Service Void - 38x50mm timber battens @600mm centres with 50mm non combustable insulation slab between battens (thermal conductivity of 0.035 W/mK).
4. Airtight OSB3 with integrated vapour control 12.5mm.
5. 44x219mm - CLS Timber Studwork @600mm centres with bio-based insulation between studs (blown cellulose shown).
6. OSB type 3 sheathing Board 11mm.
7. Reflective Breather Membrane meeting EN1928 class W1 water resistance
8. 75mm Cavity (or as required by finish)
9. External finish (as required) - Masonry Brick 102.5mm shown.

Illustrated is the Tai ar y Cyd baseline wall type which takes a solid stud approach. This can be delivered as open or closed panel under Modern Methods of Construction (MMC) definition category 2. The key requirement is to deliver a fabric U-value of 0.15 (W/m2K) utilitising a bio-based type insulation material within the frame and insulated service zone. The frame should be designed by a suitably qualified timber frame structural engineer.

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7.3.3 Supplementary Evidence

Full results for each typology could be presented as in the precedent opposite. Critical metrics are all addressed and supplemented by both a tabulated and graphical breakdown of emissions by building element.

Full Results

Table 2 reports the full results as required by RICS, RIBA and LETI, with emissions split into building element categories and subdivided into lifecycle stages. Red dots indicate items included in RIBA totals. Blue dots indicate items included in LETI totals.

Note that 'Stairs and ramps' in this case includes the external decking, as it forms part of the access into the dwelling.

Table 2. Full RICS, RIBA and LETI results, split by lifecycle stage and building element category.

Embodied CO_2 $kgCO_2e/m^2$, GIA

	Building element category	A1-A3 Manufacture	A1-A3 Sequestered	A4 Transport to site	A5 Construction	B1, B2, B3	B4, B5	C1-4	D	
Facilitating works	Toxic Material Treatment							0	0	
	Major Demolition Works							0	0	
	Temporary Enabling Works	1	-2	0	Estimated using RICS as a total only (C1 is also only given as a total, so is in the 3 totals but not the table)	0	0	3	0	● RIBA ● LETI
	Specialist Ground works	0	0	0		0	0	0	0	● RIBA ● LETI
Substructure	Substructure	132	0	15		-11	0	-1	0	● RIBA ● LETI
Superstructure	Frame	0	0	0		0	0	0	0	● RIBA ● LETI
	Upper floors incl. balconies	6	-38	2		0	0	40	-11	● RIBA ● LETI
	Roof and Built-in PV	46	-97	8		0	23	86	-30	● RIBA ● LETI
	Stairs and ramps	1	-9	1		0	2	10	-4	● RIBA ● LETI
	External Walls	22	-188	11		0	8	202	-11	● RIBA ● LETI
	Windows and External Doors	10	0	1		1	12	0	0	● RIBA ● LETI
	Internal Walls and Partitions	8	-36	3		0	0	37	-12	● RIBA ● LETI
	Internal Doors	0	0	0		0	0	0	0	● RIBA ● LETI
Finishes	Wall Finishes	2	0	1		0	0	1	0	● RIBA ● LETI
	Floor Finishes	0	0	0		0	0	0	0	● RIBA ● LETI
	Ceiling Finishes	1	-12	0		0	0	14	0	● RIBA ● LETI
FF&E	FF&E (fixed)	0	0	0		0	0	0	0	● RIBA ● LETI
	FF&E (non-fixed)	0	0	0		0	0	0	0	● RIBA
Building Services	Building services	13	0	0		0	10	0	0	● RIBA ● LETI
	Refrigerant Leakage	0	0	0		0	0	0	0	● RIBA
	Renewable Electricity Generation	17	0	0		0	34	0	0	● RIBA
Prefab	Prefab Building Units	0	0	0		0	0	0	0	● RIBA ● LETI
Existing	Minor Demolition and Alterations	0	0	0		0	0	0	0	● RIBA ● LETI
External	External Works	0	0	0		0	0	0	0	
	LETI Total ●	241	-383	45	19	-10	56	394	-69	
	RIBA Total ●	258	-383	45	19	-10	90	394	-69	
	All	258	-383	45	19	-10	90	394	-69	

Figure 4 draws from Table 2 to show the proportion of emissions relating to each building element category.

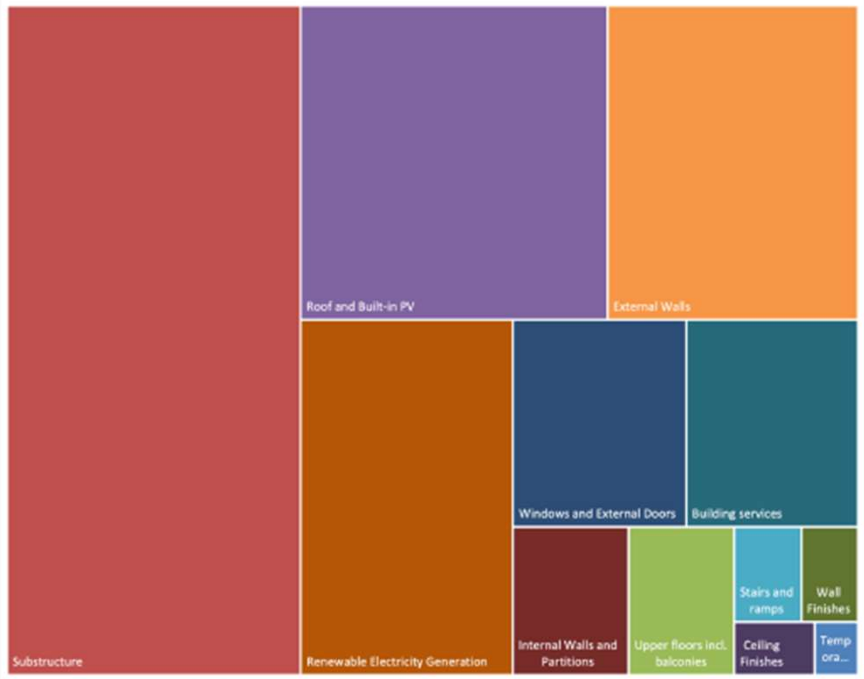

Figure 4. Proportion of A-C emissions resulting from each building element category

Upfront Material Emissions

Figure 5 shows the emissions allocated to the different material groups. Steel includes the roof covering, gutter and downpipes, MVHR ducts, and also the MVHR and Heat Pump units (in reality the latter comprise a number of different materials, but they are allocated to a single material in the assessment).

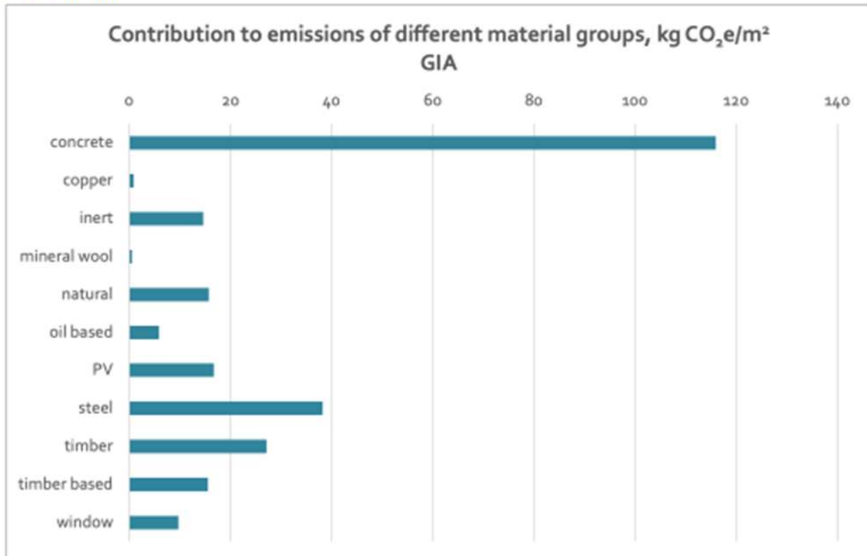

Figure 5. Contribution to A1-A3 emissions of different material groups.

Unit 2
Chapel Barns
Merthyr Mawr
Bridgend
CF32 0LS

T: 01656 656267
W: www.spring-consultancy.co.uk

Architecture
Low Energy Consultancy
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