Monmouthshire County Council

Net Zero Carbon Homes
Feasibility Study and Cost Assessment

Work Stage 3 Cost Analysis

Project Ref: 2774

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Revision: -

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 Monmouthshire County Council in developing suitably evidenced Net Zero policy to guide, assess and determine applications for new-build residential development within the emerging Replacement Local Development Plan 2018-2033.

This process has been divided into distinct work stages:

Work Stage 1.1 Policy Review
2 Policy Approach
3 Evidence Base

Work Stage 2.1 Methodologies
2 Technical Feasibility

Work Stage 3.1 Cost Analysis

Work Stage 4.1 Evidence
2 Cost Implications
3 Scrutiny Skillset

Work Stage 5 Examination

This report summarises the assumptions informing and the results of whole life carbon assessment of Work Stage 3.1 Cost Analysis.

1.2 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. Space heating demand was the only critical threshold applied for compliance purposes.

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. EUI enables the calculation of total electricity bills and, by analysis of its constituent parts, regulated energy use.

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

Operational emission scenarios	
Reference	Space heating demand
AD: L (Wales) 2025	N/A
AECB CarbonLite	40 kWh/m²/yr
MCC	25 kWh/m²/yr
LETI	15 kWh/m²/yr

The space heating demands follow the thresholds for which they are named including the newly introduced "MCC" (Monmouthshire County Council) reflecting the proposed policy position.

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. $kgCO_2e/m^2$), 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.

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.

1.3.4 Archetypes

HT 211 - GIA c. 47 m² per dwelling
Three storey block of 9x one bedroom, two person flats accessed via communal core designed to WDQR 2021 and Lifetime Homes 2010.

Form factor: 1.97

HT 212 - GIA c. 54m² per dwelling
Two storey block of 4x one bedroom, two person walk-up flats with individual accesses designed to WDQR 2021 and Lifetime Homes 2010.

Form factor: 2.99

HT 421 - GIA 83m² per dwelling
Semi-detached two bedroom, four person houses designed to WDQR 2021 and Lifetime Homes 2010.

Form factor: 3.08

HT 900 - GIA 84 m² (900 ft²) per dwelling
Semi-detached three bedroom, five person houses for open market sale.

Form factor: 3.01

HT 1800 - GIA 168 m² (1800 ft²)
Detached four bedroom, eight person house for open market sale.

Form factor: 2.89

HT 2200 - GIA 211 m² (2200 ft²)
Detached four bedroom, eight person house for open market sale.

Form factor: 2.62

Section 2: Summary

2.1 Executive Summary

As evidenced in Work Stage 2.1 Technical Feasibility, substantial operational energy savings are achievable with minor revisions to specifications with resulting reductions in operational carbon emissions.

This report assesses the relative costs associated with constructing buildings that match regulated energy demand with on-site renewable generation. Six residential new-build typologies were costed to establish the cost at various scales of development:

- **HT 211** - 3 storey block of nine flats;
- **HT 212** - 2 storey block of four walk-up flats;
- **HT 421** - two semi-detached dwellings;
- **HT 900** - two semi-detached dwellings (900ft²);
- **HT 1800** - detached single family dwelling (1800ft²);
- **HT 2200** - detached single family dwelling (2200ft²).

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;
- **MCC** - 25 kWh/m²/yr threshold;
- **LETI** - 15 kWh/m²/yr threshold.

Cost analysis established the baseline of achieving the anticipated **AD: L (Wales) 2025** requirements and examined the implications of necessary upgrades to achieve **AECB CarbonLite**, **MCC** and **LETI**. Identical construction fabric was assumed across all scenarios applying the Tai ar y Cyd baseline specification. This is anticipated to become the standard to which all social housing is delivered in Monmouthshire.

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 cost analysis

- Window upgrades £1.25 - 8k per unit
- MVHR upgrades £4 - 5k per unit
- Heating demand reductions > 80%
- EUI & CO_2e reductions 30-60%
- Regulated energy reductions 50-60%
- 40-50% fewer PV panels required
- Fewer PV panels & smaller heating systems generate CapEx savings
- CapEx uplift limited to 0.70 – 2.73% upgrading beyond AD: L (Wales) 2025

Upgrading **AD: L (Wales) 2025** to **AECB CarbonLite**, **MCC** and **LETI** requires only minor specification changes complemented by improved design - mitigating thermal bridges - and build - achieving better airtightness - quality. Accounting for the influence of these two aspects an identical building fabric can deliver the four operational scenarios across the six archetypes by varying only the doors, windows and ventilation strategy.

Cost implications of these adjustments are explored for each archetype in the tables opposite and overleaf. Baseline costs for construction are listed out under **AD: L (Wales) 2025** with the upgrade to achieve each alternative scenario under the relevant headline. Total costs are presented as cumulative totals, cost per unit and cost per m² with this also expressing the uplift as a percentage on top of the baseline.

Cost analysis demonstrates a CapEx uplift of 0.70-4.33% to upgrade the baseline to higher performance standards and match regulated energy demand with on-site renewable energy generation. If the apartment typology **HT 211** is excluded from this analysis (refer to commentary in 3.1.1 HT 211) this range reduces to

HT 211 cost analysis						
Construction	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£36,000.00					
Ground floor	£82,080.00					
External walls	£191,488.50					
Party walls	£87,855.00					
Internal walls	£60,030.00					
Separating floor	£115,560.00					
Roof	£77,016.00					
Doors & windows	£17,600.00	£21,736.00		£25,110.00		£25,110.00
FF&F	£112,246.50					
M&E	£203,805.00	£226,305.00		£238,905.00		£237,105.00
Preliminaries	£122,963.88	£126,293.38		£128,290.13		£128,065.13
TOTAL	**£1,106.674.88**	**£1,136,640.38**		**£1,154,611.13**		**£1,152,586.13**
Cost per unit	£122,963.88	£126,293.38		£128,290.13		£128,065.13
Cost per m²	£2,182.79	+2.71%	£2,241.89	+4.33%	£2,277.34	+4.15%	£2,273.35

HT 212 cost analysis						
Construction	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£17,875.00					
Ground floor	£44,460.00					
External walls	£86,627.50					
Party walls	£36,450.00					
Internal walls	£37,410.00					
Separating floor	£34,828.50					
Roof	£52,616.50					
Doors & windows	£12,095.00	£15,436.00		£17,715.00		£17,715.00
FF&F	£48,937.00					
M&E	£99,780.00	£102,180.00		£106,980.00		£106,980.00
Preliminaries	£58,759.94	£59,274.44		£60,362.44		£60,362.44
TOTAL	**£528,839.44**	**£533,469.94**		**£543,261.94**		**£543,261.94**
Cost per unit	£132,209.86	£133,367.48		£135,815.48		£135,815.48
Cost per m²	£2,350.40	+0.88%	£2,370.98	+2.73%	£2,414.50	+2.73%	£2,414.50

Cost analysis						
Construction	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£13,000.00					
Ground floor	£41,800.00					
External walls	£83,799.00					
Party walls	£15,795.00					
Internal walls	£26,100.00					
Intermediate floor	£9,680.00					
Roof	£38,948.00					
Doors & windows	£6,930.00	£9,467.00		£11,149.00		£11,149.00
FF&F	£37,158.00					
M&E	£55,090.00	£55,490.00		£58,690.00		£57,890.00
Preliminaries	£41,092.50	£41,481.63		£42,091.88		£41,991.88
TOTAL	**£369,832.50**	**£373,334.63**		**£378,826.88**		**£377,926.88**
Cost per unit	£184,916.25	£186,667.31		£189,413.44		£188,963.44
Cost per m²	£2,222.55	+0.95%	£2,243.60	+2.43%	£2,276.60	+2.19%	£2,271.20

0.70-2.73% while delivering at least a 45% reduction in regulated energy demand which can be extrapolated into significant life cycle cost savings for households.

Despite the additional cost of installing MVHR instead of dMEV, savings are possible due to the reduction in space heating demand requiring smaller ASHPs and photovoltaic arrays. HT 211 is an outlier for two reasons: firstly that in applying the standard fabric specification it significantly overperforms for each low energy scenario; secondly that a standardised MEP specification uses the same ASHP - the smallest commercially available of this type - in each scenario, failing to leverage the reduced space heating demand to deliver cost efficiencies. Alternative heating strategies could generate CapEx savings.

While immediate cost uplift is perceived with replacing MEV with MVHR, heat recovery reduces the heating demand and EUI. If aiming to match regulated energy demand and on-site renewable generation, capital costs of MVHR are quickly justified by the savings it can leverage from smaller heating systems (ASHPs) photovoltaic arrays and operational cost savings for the life of the building(s).

Remaining variations are within window specifications, levels of airtightness and mitigation of thermal bridges. Windows have negligible impact on total project costs; airtightness and thermal bridging can be improved without additional expenditure through a combination of 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 match regulated energy demand and require more investment in photovoltaics and other technologies to balance it. 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, EUI and regulated energy demand. If the aspiration is to deliver affordable warmth within decarbonised homes then pursuing a lower specification 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 regulated 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 energy demand.

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. 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.

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.

HT 900 cost analysis						
Construction	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£13,500.00					
Ground floor	£42,560.00					
External walls	£84,540.00					
Party walls	£16,200.00					
Internal walls	£26,390.00					
Intermediate floor	£10,350.00					
Roof	£38,911.00					
Doors & windows	£7,700.00	£10,276.00		£11,432.00		£11,432.00
FF&F	£39,242.00					
M&E	£57,690.00	£57,290.00		£60,490.00		£59,690.00
Preliminaries	£42,135.38	£42,429.88		£42,974.38		£42,874.38
TOTAL	**£379,218.38**	**£381,868.88**		**£386,769.38**		**£385,869.38**
Cost per unit	£189,609.19	£190,934.44		£193,384.69		£192,934.69
Cost per m²	£2,251.89	+0.70%	£2,267.63	+1.99%	£2,296.73	+1.75%	£2,291.39

HT 1800 cost analysis						
Construction	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£12,250.00					
Ground floor	£36,860.00					
External walls	£74,363.00					
Party walls	N/A					
Internal walls	£27,550.00					
Intermediate floor	£8,855.00					
Roof	£49,429.00					
Doors & windows	£8,770.00	£12,518.00		£16,120.00		£16,120.00
FF&F	£36,250.00					
M&E	£33,720.00	£34,895.00		£35,245.00		£34,845.00
Preliminaries	£36,205.88	£36,640.50		£37,134.50		£37,084.50
TOTAL	**£325,852.88**	**£329,764.50**		**£334,210.50**		**£333,760.50**
Cost per unit	£325,852.88	£329,764.50		£334,210.50		£333,760.50
Cost per m²	£1,940.76	+1.20%	£1,964.05	+2.56%	£1,990.53	+2.43%	£1,987.85

HT 2200 cost analysis						
Construction	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£14,250.00					
Ground floor	£41,800.00					
External walls	£89,359.50					
Party walls	N/A					
Internal walls	£39,005.00					
Intermediate floor	£12,075.00					
Roof	£51,997.00					
Doors & windows	£9,470.00	£13,018.00		£17,440.00		£17,440.00
FF&F	£38,625.00					
M&E	£35,620.00	£34,895.00		£35,245.00		£34,845.00
Preliminaries	£41,525.19	£41,904.31		£42,500.81		£42,450.81
TOTAL	**£373,726.69**	**£377,138.81**		**£382,507.31**		**£382,057.31**
Cost per unit	£373,726.69	£377,138.81		£382,507.31		£382,057.31
Cost per m²	£1,773.74	+0.91%	£1,789.93	+2.35%	£1,815.41	+2.23%	£1,813.28

Section 3: Cost Analysis

3.1 Residential

3.1.1 HT 211

This section contains a summary of the operational assessment of **HT 211** with high-level costings followed by detailed cost analyses on page 8. 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 achieved by flats, delivering significantly reduced space heating demand versus the applicable thresholds. AECB CarbonLite and MCC achieve approximately 50% reductions on the targeted space heating demand while LETI reduces to less than 25% of the requirement.

This typology illustrates that applying a standard specification is not the most efficient or economical way of achieving low energy building standards. Apartments and other buildings with good form factor can implement a lower fabric specification and still achieve the highest levels of performance. Reducing the fabric specification - in its simplest form, reducing the thickness of insulation - could lower build costs and achieve savings for developers.

AD: L (Wales) 2025 establishes the baseline for comparisons. Space heating demand is calculated at 63.7 kWh/m²/yr with an EUI of 75.3 kWh/m²/yr of which regulated energy comprises 61.1 kWh/m²/yr.

AECB CarbonLite reduces space heating demand more than 65% from AD: L (Wales) 2025 and accomplishes a 50% reduction in EUI. Regulated energy demand falls 60% and therefore 40% of the photovoltaics are required to meet energy demand.

Applying the standardised specification for MCC's chosen policy position reduces space heating demand 80% from AD: L (Wales) 2025 and results in an almost 60% reduction in EUI and 70% reduction in regulated energy use, requiring a third of the photovoltaics.

Operational outputs					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	Regulated energy demand	PV per dwelling to meet regulated
1 AD: L (Wales) 2025	63.7 kWh/m^2_{TFA}/yr	75.3 kWh/m^2_{GIA}/yr	3,586 kWh/yr	61.1 kWh/m^2_{GIA}/yr	3.4 kWp
2 AECB CarbonLite	20.9 kWh/m^2_{TFA}/yr	38.2 kWh/m^2_{GIA}/yr	1,819 kWh/yr	23.9 kWh/m^2_{GIA}/yr	1.3 kWp
3 MCC	11.9 kWh/m^2_{TFA}/yr	32.6 kWh/m^2_{GIA}/yr	1,550 kWh/yr	18.3 kWh/m^2_{GIA}/yr	1.0 kWp
4 LETI	3.4 kWh/m^2_{TFA}/yr	28.2 kWh/m^2_{GIA}/yr	1,342 kWh/yr	13.9 kWh/m^2_{GIA}/yr	0.8 kWp

Cost analysis							
Construction	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£36,000.00						
Ground floor	£82,080.00						
External walls	£191,488.50						
Party walls	£87,855.00						
Internal walls	£60,030.00						
Separating floor	£115,560.00						
Roof	£77,016.00						
Doors & windows	£17,600.00		£21,736.00		£25,110.00		£25,110.00
FF&F	£112,246.50						
M&E	£203,805.00		£226,305.00		£238,905.00		£237,105.00
Preliminaries	£122,963.88		£126,293.38		£128,290.13		£128,065.13
TOTAL	**£1,106.674.88**		**£1,136,640.38**		**£1,154,611.13**		**£1,152,586.13**
Cost per unit	£122,963.88		£126,293.38		£128,290.13		£128,065.13
Cost per m²	£2,182.79	+2.71%	£2,241.89	+4.33%	£2,277.34	+4.15%	£2,273.35

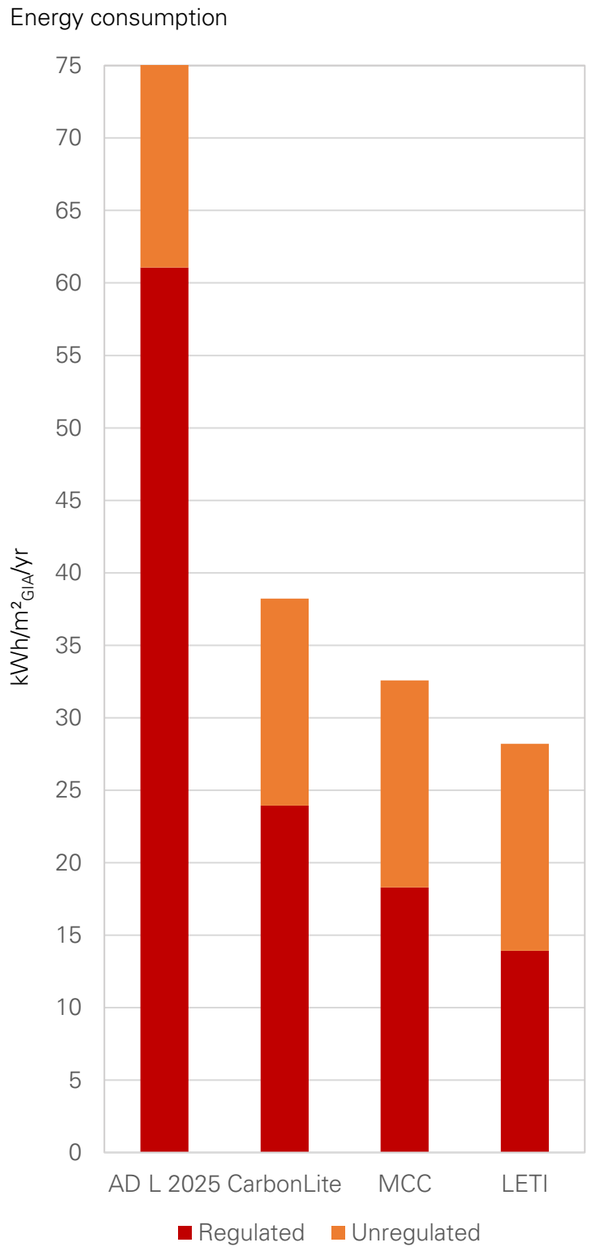
Space heating demand reduces more than 90% from AD: L (Wales) 2025 to LETI. This achieves more than 60% reduction in EUI and almost 80% reduction in regulated energy, requiring less than a quarter of the photovoltaics to balance regulated use.

Cost analysis presents the relative costs apportioned to various building components to achieve the defined operational scenarios. As standardised constructions achieve all levels of operational energy performance the majority of elements attract identical costs with the only differences in Doors & windows, M&E and - resultingly - Preliminaries which are charged at 12.5%.

Improvements to the specification attract an uplift of 3-4% to achieve the operational standards beyond the AD: L (Wales) 2025 baseline.

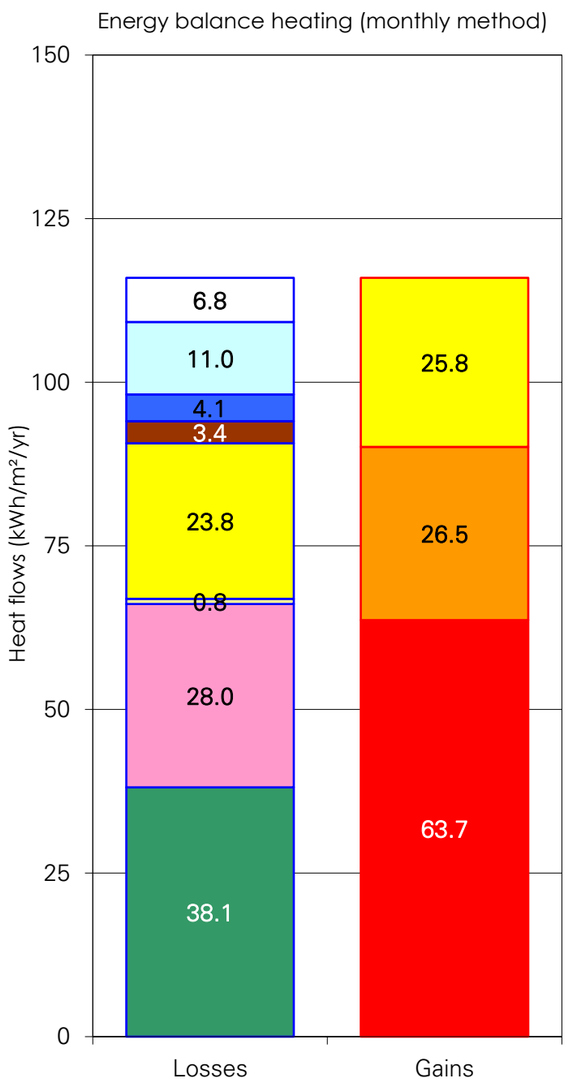
Energy consumption graphed opposite shows how use is split between regulated (heating, domestic hot water, ventilation and lighting) and the unregulated household uses. Regulated energy is represented in red with the already discussed reductions clearly illustrated between the operational scenarios.

As the occupancy and appliances were identical between all modelled scenarios, unregulated energy use - captured in orange - is the same in each instance.

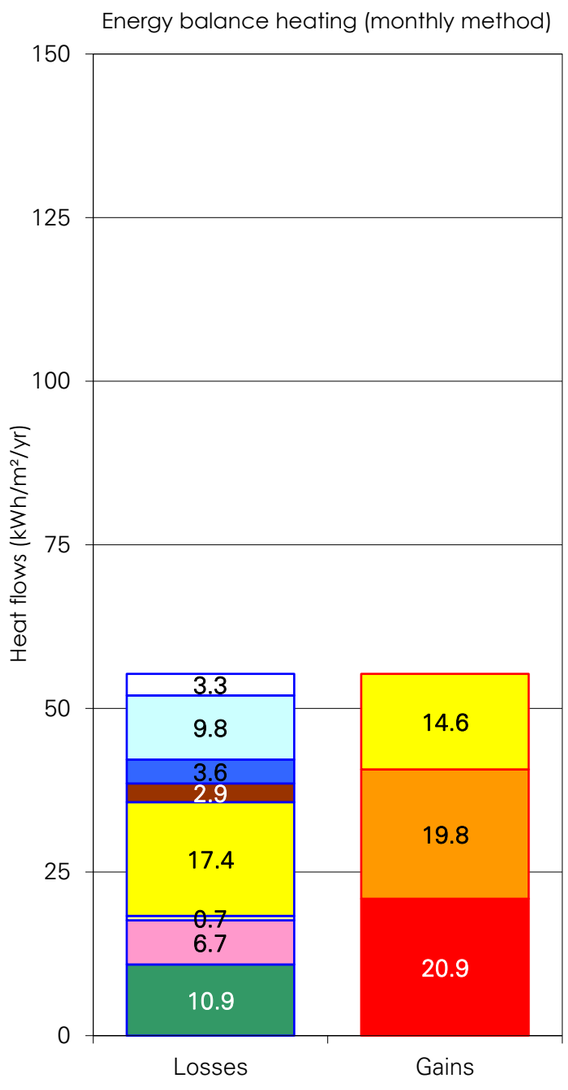


Operational Scenarios

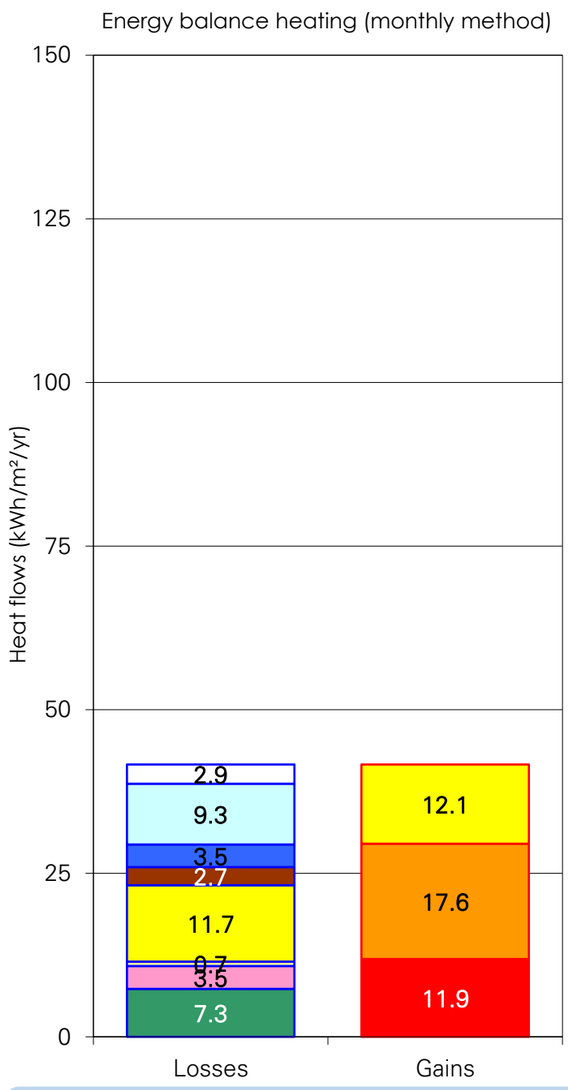
HT 211 - AD: L (Wales) 2025



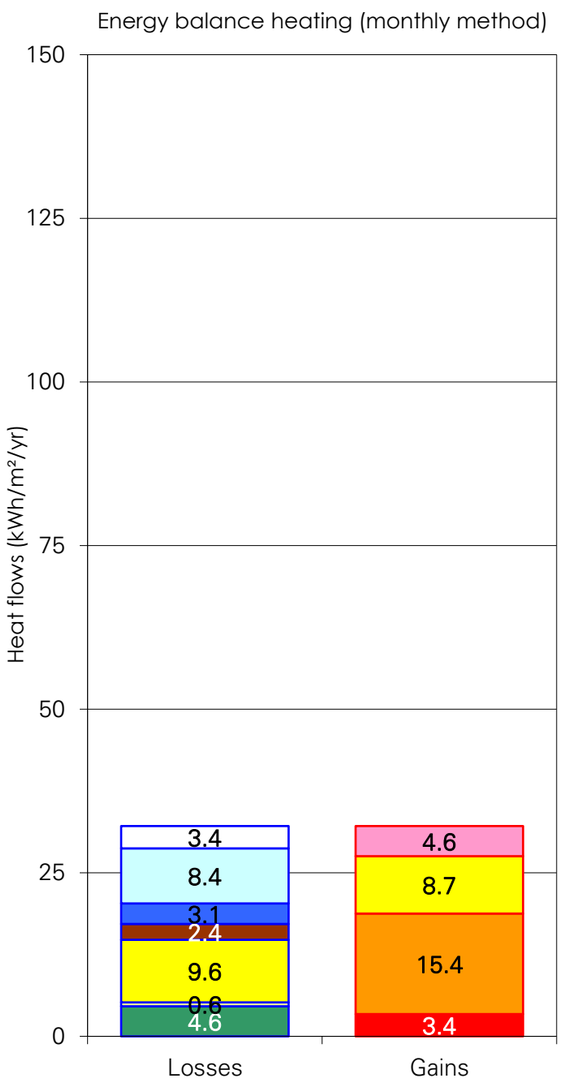
HT 211 - AECB CarbonLite



HT 211 - MCC



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 2025 electricity unit rate of £0.27 per kWh

Projected Annual Electricity Bills

- AD:L (Wales) 2025 £968.22
- AECB CarbonLite £491.13
- MCC £418.50
- LETI £362.34

excludes standing charge & PV offsets

Construction element	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI	
Foundations	Concrete trench fill	£36,000.00						
		£36,000.00						
Ground floor	Sand & cement screed	£14,040.00						
	PIR insulation	£29,160.00						
	Beam & block floor	£38,880.00						
		£82,080.00						
External walls	Plasterboard w/ skim	£16,695.00						
	Timber battens w/ Isover 32	£10,732.50						
	SmartPly Pro Passiv OSB	£31,005.00						
	Timber studs w/ Isover 32	£39,600.00						
	Medite Vent sheathing board	£19,536.00						
	Breather membrane	£2,112.00						
	Ventilated cavity	£528.00						
	Brickwork	£71,280.00						
		£191,488.50						
Party walls	Plasterboard w/ skim	£10,850.00						
	Timber stud w/ Isover 32	£15,190.00						
	Smartply Pro Passiv OSB	£14,105.00						
	Isover 32 filled cavity	£7,595.00						
	Smartply Pro Passiv OSB	£14,105.00						
	Timber stud w/ Isover 32	£15,190.00						
	Plasterboard w/ skim	£10,850.00						
		£87.885.00						
Internal walls	Plasterboard w/ skim	£14,490.00						
	Timber stud w/ Isover 32	£31,050.00						
	Plasterboard w/ skim	£14,490.00						
		£60,030.00						
Separating floor	Stairs	£6,750.00						
	Cellecta Screedboard 28	£20,880.00						
	OSB deck	£16,200.00						
	W. joists w/ mineral wool	£20,880.00						
	Resilient bars w/ p-board	£30,600.00						
	Sus. ceiling w/ p-board	£27,000.00						
		£115,560.00						
Roof	Plasterboard w/ skim	£7,200.00						
	Battened service zone	£180.00						
	SmartPly Pro Passiv OSB	£14,040.00						
	Knauf Earthwool 40 insulation	£15,120.00						
	Timber trusses	£17,280.00						
	Ventilated attic	£216.00						
	Tile battens	£5,400.00						
	Concrete tiles	£14,040.00						
	Rainwater goods	£3,540.00						
		£77,016.00						
External doors & windows	Windows PAS 24 DG	£14,600.00	Windows Rehau Artevo DG	£18,736.00	Windows Rehau Artevo TG	£21,610.00	Windows Rehau Artevo TG	£21,610.00
	External doors	£3,000.00	External doors	£3,000.00	External doors	£3,500.00	External doors	£3,500.00
		£17,600.00		**£21,736.00**		**£25,110.00**		**£25,110.00**
Finishes, fixtures & fittings	Internal doors	£38,250.00						
	Floor finishes	£1,404.00						
	Wall finishes	£21,189.00						
	Ceiling finishes	£6,403.50						
	Kitchen F&F	£31,500.00						
	Shower room F&F	£13,500.00						
		£112,246.50						
M&E	General electrical circuit	£49,500.00	General electrical circuit	£49,500.00	General electrical circuit	£49,500.00	General electrical circuit	£49,500.00
	3.5 kW ASHPs w/ cylinders	£114,750.00	3.5 kW ASHPs w/ cylinders	£114,750.00	3.5 kW ASHPs w/ cylinders	£114,750.00	3.5 kW ASHPs w/ cylinders	£114,750.00
	MEV units (2 per unit)	£3,600.00	EnergiSava 300 MVHR units	£44,100.00	Zehnder ComfoAir 225 units	£58,500.00	Zehnder ComfoAir 225 units	£58,500.00
	PV panels (9 per unit)	£35,995.00	PV panels (4 per unit)	£17,955.00	PV panels (3 per unit)	£16,155.00	PV panels (2 per unit)	£14,355.00
		£203,805.00		**£226,305.00**		**£238,905.00**		**£237,105.00**
Preliminaries (12.5%)		**£122,963.88**		**£126,293.38**		**£128,290.13**		**£128,065.13**
TOTAL		**£1,106,674.88**	+2.71% uplift	**£1,136,640.38**	+4.33% uplift	**£1,154,611.13**	+4.15% uplift	**£1,152,586.13**

HT 211 cost analysis headlines

- Windows increase in cost c. 150% but substantially reduce heat losses
- MVHR most significant CapEx uplift but offsets with reduction in heating demand, regulated demand & PV
- 3.5 kW ASHP for all scenarios
- Lower regulated demand requires far less PV provision
- Capital cost uplift limited to 3-4%
- Regulated energy savings of > 60%

Critical components of the thermal envelope varied between the operational scenarios are highlighted in green. Note there is no difference between the fabric except for doors and windows: the rest of the fabric is capable of achieving all standards if properly detailed.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue.

Peculiar to this typology, all operational scenarios employ the same 3.5 kW ASHP. There would generally be a pattern of reduced ASHP sizes (and costs) as operational standards improve but the small size of each apartment results in relatively low heating loads.

Reduced photovoltaic provisions produce CapEX savings that partially offset the cost uplift associated with upgrading from MEV to MVHR: heating demand savings assisted by MVHR reduce overall energy consumption by 50-65% and regulated energy demand by 60-70%.

3.1.2 HT 212

This section contains a summary of the operational assessment of **HT 212** with high-level costings followed by detailed cost analyses on page 11. For illustrative drawings of the building and its modelled context, please refer to 5: Appendices.

Operational outputs demonstrate that despite generally improved form factor within flats there are certain inefficiencies for walk-up typologies. However, the standardised specifications achieve the defined space heating demand of each operational scenario.

AD: L (Wales) 2025 establishes the baseline for comparisons. Space heating demand is calculated at 85.4 kWh/m²/yr with an EUI of 66.9 kWh/m²/yr of which regulated energy comprises 51.1 kWh/m²/yr.

AECB CarbonLite reduces space heating demand almost 60% from AD: L (Wales) 2025 and accomplishes a 40% reduction in EUI. Regulated energy demand falls 55% and therefore 45% of the photovoltaics are required to meet energy demand.

MCC's chosen policy position reduces space heating demand 70% from AD: L (Wales) 2025. This produces an almost 45% reduction in EUI and approximately 60% reduction in regulated energy that requires 40% of the photovoltaic provisions.

Space heating demand reduces more than 85% from AD: L (Wales) 2025 to LETI. This achieves more than 50% reduction in EUI and almost 65% reduction in regulated energy, requiring 35% of the photovoltaics to balance regulated use.

Operational outputs					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	Regulated energy demand	PV per dwelling to meet regulated
1 AD: L (Wales) 2025	85.4 kWh/m²$_{TFA}$/yr	66.9 kWh/m²$_{GIA}$/yr	3,630 kWh/yr	51.1 kWh/m²$_{GIA}$/yr	3.8 kWp
2 AECB CarbonLite	36.5 kWh/m²$_{TFA}$/yr	39.2 kWh/m²$_{GIA}$/yr	2,126 kWh/yr	23.4 kWh/m²$_{GIA}$/yr	1.8 kWp
3 MCC	24.9 kWh/m²$_{TFA}$/yr	36.7 kWh/m²$_{GIA}$/yr	1,992 kWh/yr	21.0 kWh/m²$_{GIA}$/yr	1.6 kWp
4 LETI	12.8 kWh/m²$_{TFA}$/yr	34.0 kWh/m²$_{GIA}$/yr	1,847 kWh/yr	18.3 kWh/m²$_{GIA}$/yr	1.4 kWp

Cost analysis							
Construction	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£17,875.00						
Ground floor	£44,460.00						
External walls	£86,627.50						
Party walls	£36,450.00						
Internal walls	£37,410.00						
Separating floor	£34,828.50						
Roof	£52,616.50						
Doors & windows	£12,095.00		£15,436.00		£17,715.00		£17,715.00
FF&F	£48,937.00						
M&E	£99,780.00		£102,180.00		£106,980.00		£106,980.00
Preliminaries	£58,759.94		£59,274.44		£60,362.44		£60,362.44
TOTAL	**£528,839.44**		**£533,469.94**		**£543,261.94**		**£543,261.94**
Cost per unit	£132,209.86		£133,367.48		£135,815.48		£135,815.48
Cost per m²	£2,350.40	+0.88%	£2,370.98	+2.73%	£2,414.50	+2.73%	£2,414.50

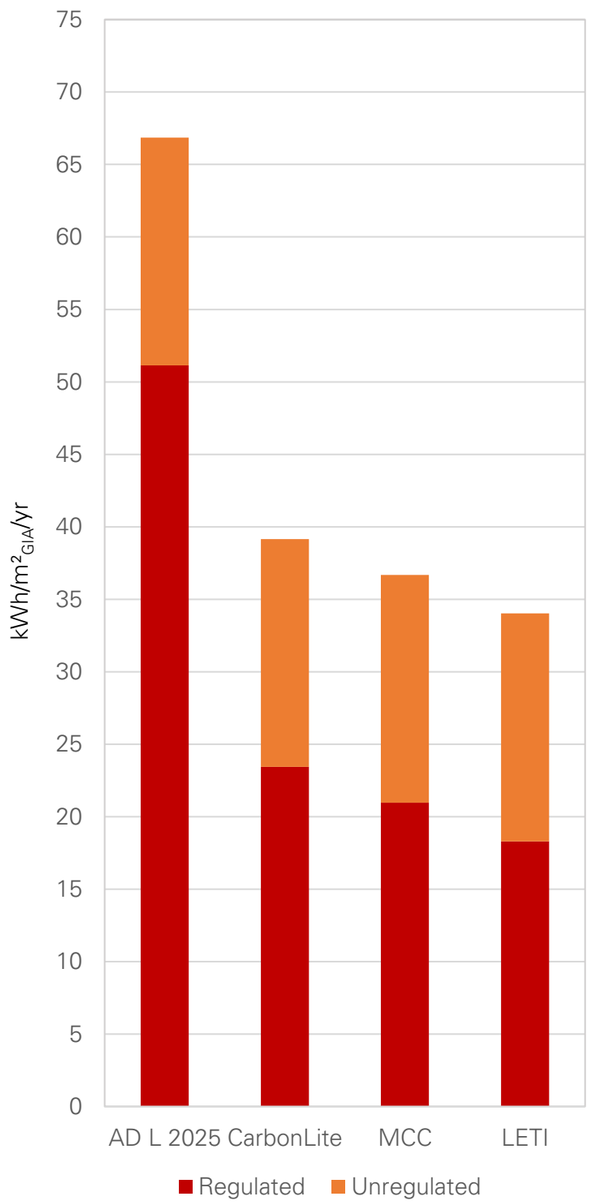
Cost analysis presents the relative costs apportioned to various building components to achieve the defined operational scenarios. As standardised constructions achieve all levels of operational energy performance the majority of elements attract identical costs with the only differences in Doors & windows, M&E and - resultingly - Preliminaries which are charged at 12.5%.

Improvements to the specification attract an uplift of 0-2% to achieve the operational standards beyond the AD: L (Wales) 2025 baseline. There is no appreciable cost difference between the MCC and LETI scenarios as these specifications are only separated by improved airtightness and thermal bridging detailing.

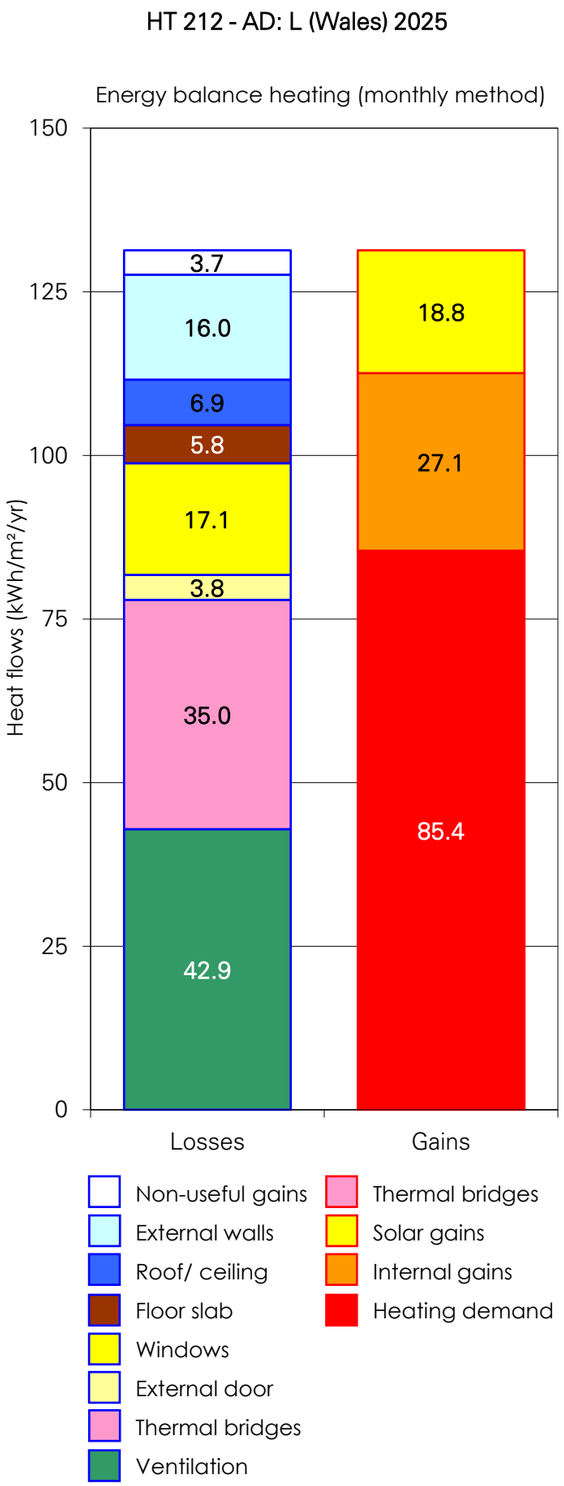
Energy consumption graphed opposite shows how use is split between regulated (heating, domestic hot water, ventilation and lighting) and the unregulated household uses. Regulated energy is represented in red with the already discussed reductions clearly illustrated between the operational scenarios.

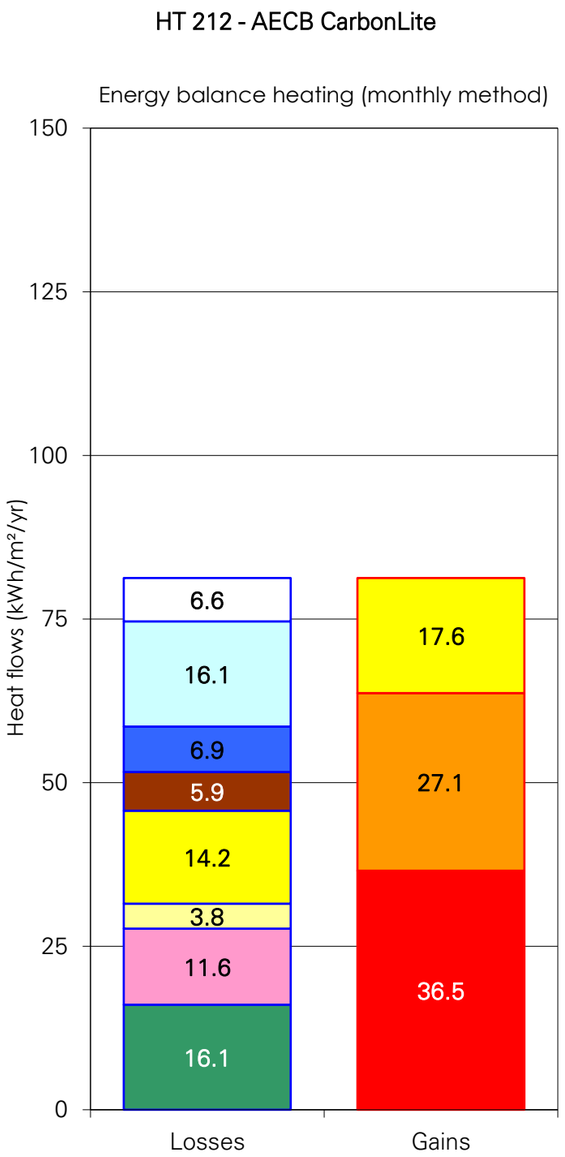
As the occupancy and appliances were identical between all modelled scenarios, unregulated energy use - captured in orange - is the same in each instance.

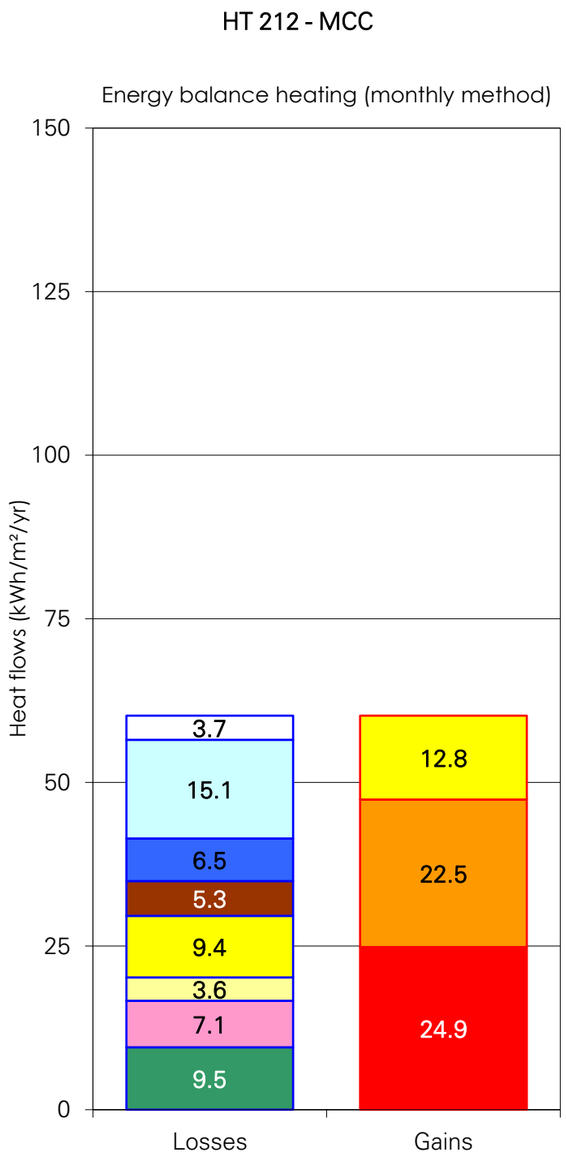
Energy consumption

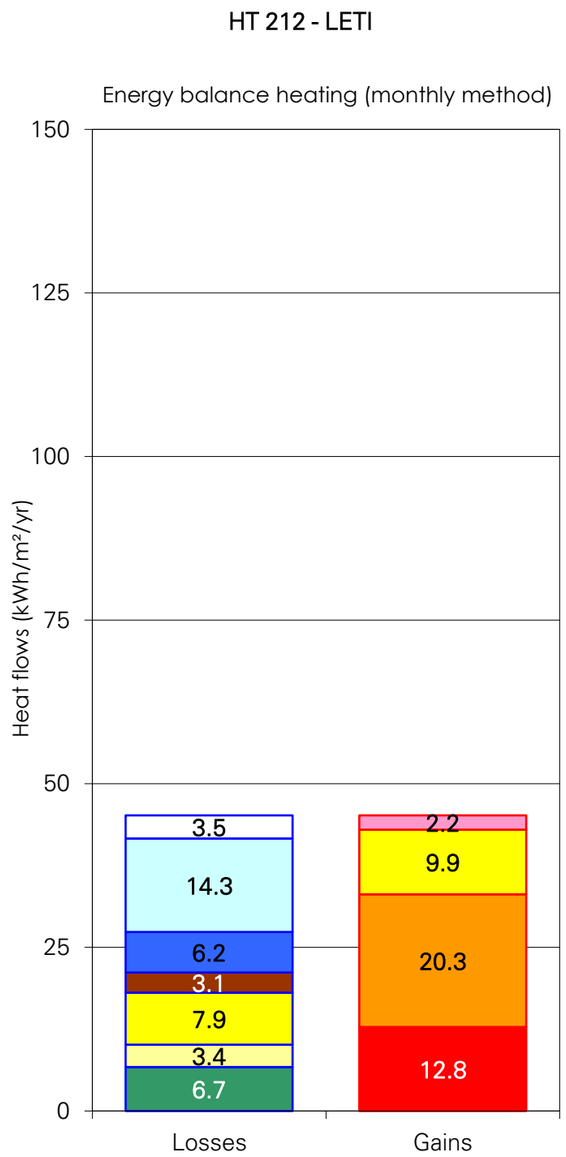


Operational Scenarios









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 2025 electricity unit rate of £0.27 per kWh

Projected Annual Electricity Bills

- AD:L (Wales) 2025 £980.10
- AECB CarbonLite £574.02
- MCC £537.84
- LETI £498.69

excludes standing charge & PV offsets

Construction element	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI	
Foundations	Concrete trench fill	£17,875.00						
		£17,875.00						
Ground floor	Sand & cement screed	£7,605.00						
	PIR insulation	£15,795.00						
	Beam & block floor	£21,060.00						
		£44,460.00						
External walls	Plasterboard w/ skim	£6,825.00						
	Timber battens w/ Isover 32	£4,387.50						
	SmartPly Pro Passiv OSB	£12,675.00						
	Timber studs w/ Isover 32	£18,375.00						
	Medite Vent sheathing board	£19,065.00						
	Breather membrane	£980.00						
	Ventilated cavity	£245.00						
	Brickwork	£33,075.00						
		£85,627.50						
Party walls	Plasterboard w/ skim	£4,500.00						
	Timber stud w/ Isover 32	£6,300.00						
	Smartply Pro Passiv OSB	£5,850.00						
	Isover 32 filled cavity	£3,150.00						
	Smartply Pro Passiv OSB	£5,850.00						
	Timber stud w/ Isover 32	£6,300.00						
	Plasterboard w/ skim	£4,500.00						
		£36,450.00						
Internal walls	Plasterboard w/ skim	£9,030.00						
	Timber stud w/ Isover 32	£19,350.00						
	Plasterboard w/ skim	£9,030.00						
		£37,410.00						
Separating floor	Stairs	£4,500.00						
	Cellecta Screedboard 28	£6,293.00						
	OSB deck	£4,882.50						
	W. joists w/ mineral wool	£6,293.00						
	Resilient bars w/ p-board	£9,222.50						
	Sus. ceiling w/ p-board	£8,137.50						
		£34,828.50						
Roof	Plasterboard w/ skim	£4,340.00						
	Battened service zone	£108.50						
	SmartPly Pro Passiv OSB	£9,945.00						
	Knauf Earthwool 40 insulation	£10,710.00						
	Timber trusses	£12,240.00						
	Ventilated attic	£153.00						
	Tile battens	£3,825.00						
	Concrete tiles	£9,945.00						
	Rainwater goods	£1,350.00						
		£52,616.50						
External doors & windows	Windows PAS 24 DG	£6,095.00	Windows Rehau Artevo DG	£9,436.00	Windows Rehau Artevo TG	£10,715.00	Windows Rehau Artevo TG	£10,715.00
	External doors	£6,000.00	External doors	£6,000.00	External doors	£7,000.00	External doors	£7,000.00
		£12,095.00		**£15,436.00**		**£17,715.00**		**£17,715.00**
Finishes, fixtures & fittings	Internal doors	£14,000.00						
	Floor finishes	£650.00						
	Wall finishes	£10,912.00						
	Ceiling finishes	£3,375.00						
	Kitchen F&F	£14,000.00						
	Shower room F&F	£6,000.00						
		£48,937.00						
M&E	General electrical circuit	£22,000.00	General electrical circuit	£22,000.00	General electrical circuit	£22,000.00	General electrical circuit	£22,000.00
	5 kW ASHPs w/ cylinders	£57,000.00	3.5 kW ASHPs w/ cylinders	£51,000.00	3.5 kW ASHPs w/ cylinders	£51,000.00	3.5 kW ASHPs w/ cylinders	£51,000.00
	MEV units (2 per unit)	£3,200.00	EnergiSava 300 MVHR units	£19,600.00	Zehnder ComfoAir 225 units	£26,000.00	Zehnder ComfoAir 225 units	£26,000.00
	PV panels (10 per unit)	£17,580.00	PV panels (5 per unit)	£9,580.00	PV panels (4 per unit)	£7,980.00	PV panels (4 per unit)	£7,980.00
		£99,780.00		**£102,180.00**		**£106,980.00**		**£106,980.00**
Preliminaries (12.5%)		**£58,759.94**		**£59,274.44**		**£60,362.44**		**£60,362.44**
TOTAL		**£528,839.44**	+0.88% uplift	**£533,469.94**	+2.73% uplift	**£543,261.94**	+2.73% uplift	**£543,261.94**

HT 212 cost analysis headlines

- Windows increase in cost c. 150% but substantially reduce heat losses
- MVHR most significant CapEx uplift but offsets with reduction in heating demand, regulated demand & PV
- 5 kW reduces to 3.5 kW ASHP
- Lower regulated demand requires less than half the PV provision
- Capital cost uplift limited to c. 3%
- Regulated energy savings of > 55%

Critical components of the thermal envelope varied between the operational scenarios are highlighted in green. Note there is no difference between the fabric except for doors and windows: the rest of the fabric is capable of achieving all standards if properly detailed.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue. Only the AD: L Wales (2025) requires a 5 kW ASHP with the remaining scenarios all able to operate with a smaller 3.5 kW ASHP. Smaller heating systems combined with reduced photovoltaic provisions produce CapEX savings that partially offset the cost uplift associated with upgrading from MEV to MVHR.

Heating demand savings assisted by MVHR reduce overall energy consumption by 40-50% and the regulated energy demand by 55-65%.

3.1.3 HT 421

This section contains a summary of the operational assessment of **HT 421** with high-level costings followed by detailed cost analyses on page 14. For illustrative drawings of the building and its modelled context, please refer to 5: Appendices.

Operational outputs demonstrate the inefficiencies associated with smaller semi-detached dwellings due to poor form factor. While achieving the defined space heating demand for both AECB CarbonLite and LETI this typology falls just short of the MCC target.

As the modelled scenarios apply the maximum altitude of strategic development sites and the least favourable building orientation, failing to achieve the threshold by less than 5% is considered acceptable and would not present the same issue on lower altitude sites. At or above the modelled 140m altitude the issue could be overcome by simply optimising orientation with no additional capital expenditure; alternatively, properties could be organised in terraces to significantly reduce space heating demand.

AD: L (Wales) 2025 establishes the baseline for comparisons. Space heating demand is calculated at 90.2 kWh/m²/yr with an EUI of 64.4 kWh/m²/yr of which regulated energy comprises 45.8 kWh/m²/yr.

AECB CarbonLite reduces space heating demand almost 60% from AD: L (Wales) 2025 and accomplishes a 30% reduction in EUI. Regulated energy demand falls 45% and therefore 55% of the photovoltaics are required to meet energy demand.

MCC's chosen policy position reduces space heating demand 70% from AD: L (Wales) 2025. This achieves an almost 35% reduction in EUI and approximately 50% reduction in regulated energy, requiring 50% of the photovoltaics.

Operational outputs					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	Regulated energy demand	PV per dwelling to meet regulated
1 AD: L (Wales) 2025	90.2 kWh/m²$_{TFA}$/yr	64.4 kWh/m²$_{GIA}$/yr	5,358 kWh/yr	45.8 kWh/m²$_{GIA}$/yr	5.2 kWp
2 AECB CarbonLite	38.7 kWh/m²$_{TFA}$/yr	44.5 kWh/m²$_{GIA}$/yr	3,700 kWh/yr	25.9 kWh/m²$_{GIA}$/yr	3.0 kWp
3 MCC	25.9 kWh/m²$_{TFA}$/yr	42.7 kWh/m²$_{GIA}$/yr	3,555 kWh/yr	24.2 kWh/m²$_{GIA}$/yr	2.8 kWp
4 LETI	15.2 kWh/m²$_{TFA}$/yr	40.5 kWh/m²$_{GIA}$/yr	3,368 kWh/yr	21.9 kWh/m²$_{GIA}$/yr	2.4 kWp

Cost analysis							
Construction	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£13,000.00						
Ground floor	£41,800.00						
External walls	£83,799.00						
Party walls	£15,795.00						
Internal walls	£26,100.00						
Intermediate floor	£9,680.00						
Roof	£38,948.00						
Doors & windows	£6,930.00		£9,467.00		£11,149.00		£11,149.00
FF&F	£37,158.00						
M&E	£55,090.00		£55,490.00		£58,690.00		£57,890.00
Preliminaries	£41,092.50		£41,481.63		£42,091.88		£41,991.88
TOTAL	**£369,832.50**		**£373,334.63**		**£378,826.88**		**£377,926.88**
Cost per unit	£184,916.25		£186,667.31		£189,413.44		£188,963.44
Cost per m²	£2,222.55	+0.95%	£2,243.60	+2.43%	£2,276.60	+2.19%	£2,271.20

Space heating demand reduces by almost 85% from AD: L (Wales) 2025 to LETI. This achieves more than 35% reduction in EUI and more than 50% reduction in regulated energy, requiring 50% of the photovoltaics to balance regulated use.

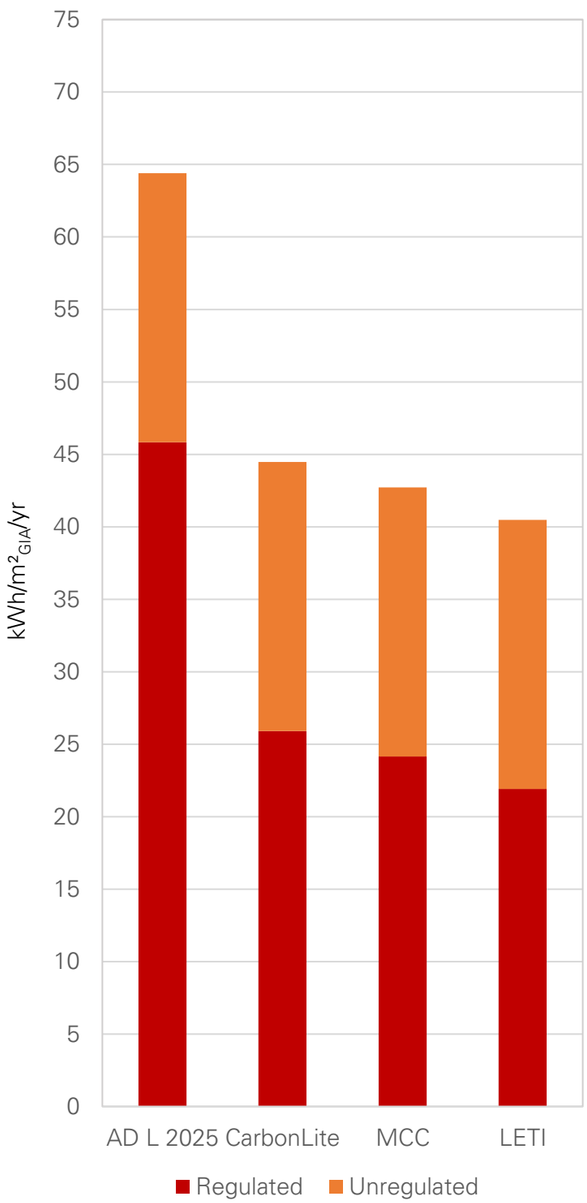
Cost analysis presents the relative costs apportioned to various building components to achieve the defined operational scenarios. As standardised constructions achieve all levels of operational energy performance the majority of elements attract identical costs with the only differences in Doors & windows, M&E and - resultingly - Preliminaries which are charged at 12.5%.

Improvements to the specification attract an uplift of 1-2% to achieve the operational standards beyond the AD: L (Wales) 2025 baseline. MCC attracts a slightly higher cost than LETI as, while only detailing and build quality separates the specifications, LETI requires fewer photovoltaics to balance energy consumption.

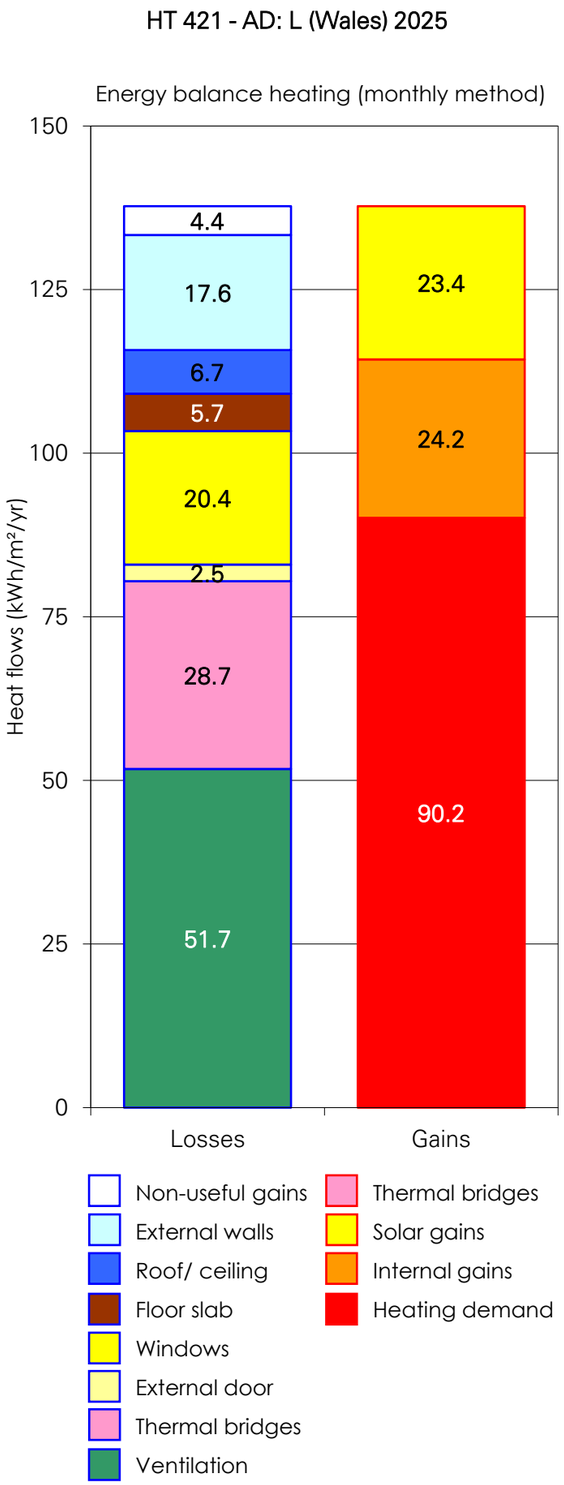
Energy consumption graphed opposite shows how use is split between regulated (heating, domestic hot water, ventilation and lighting) and the unregulated household uses. Regulated energy is represented in red with the already discussed reductions clearly illustrated between the operational scenarios.

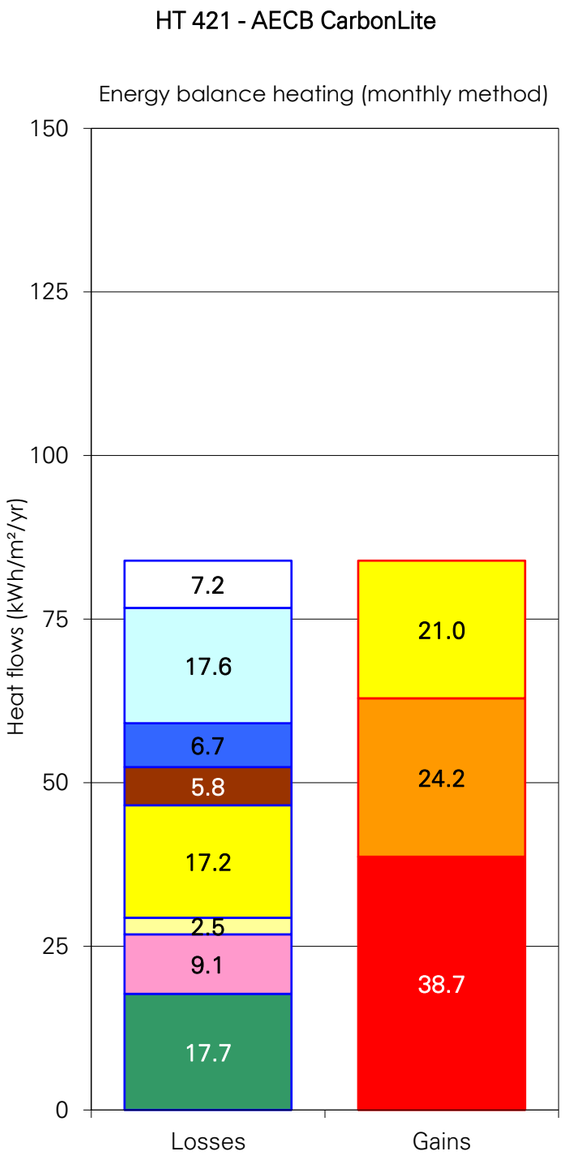
As the occupancy and appliances were identical between all modelled scenarios, unregulated energy use - captured in orange - is the same in each instance.

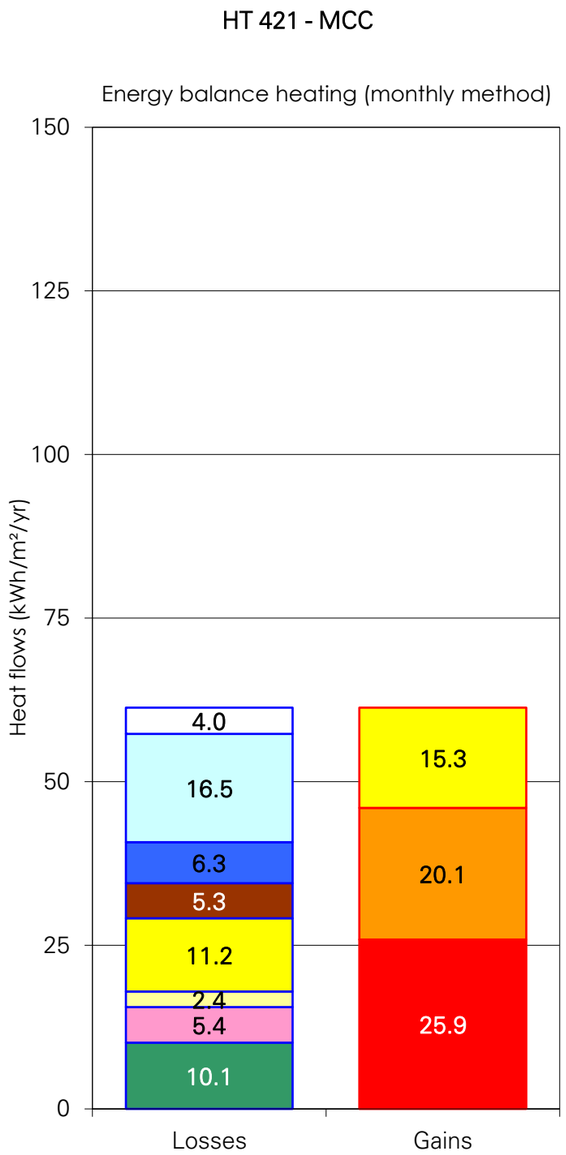
Energy consumption

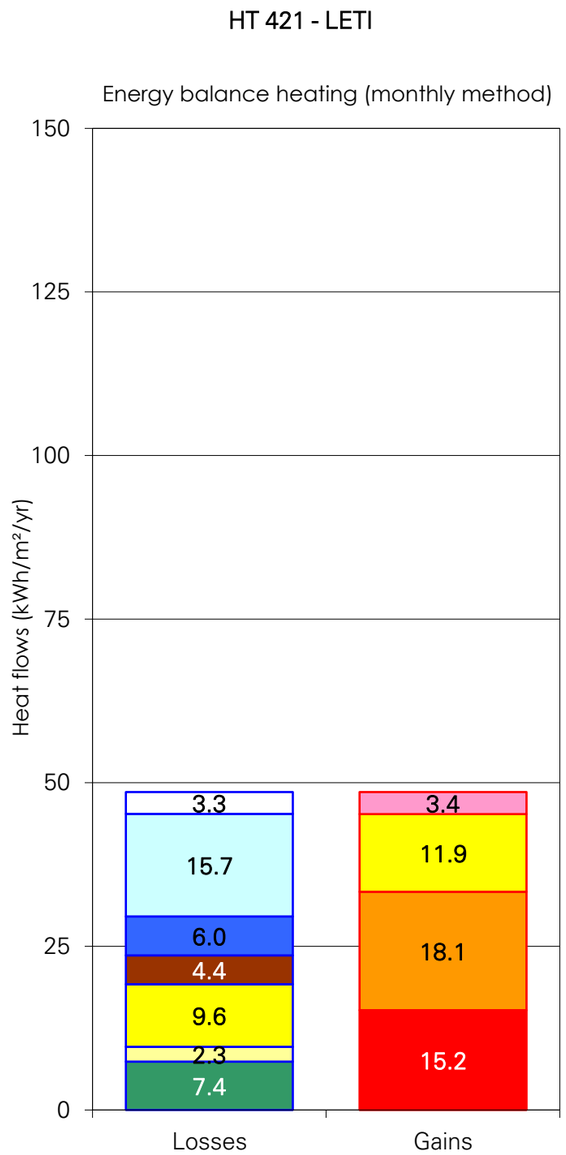


Operational Scenarios









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 2025 electricity unit rate of £0.27 per kWh

Projected Annual Electricity Bills

• AD:L (Wales) 2025	£1,446.66
• AECB CarbonLite	£999.00
• MCC	£959.85
• LETI	£909.36

excludes standing charge & PV offsets

Construction element	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI	
Foundations	Concrete trench fill	£13,000.00						
		£13,000.00						
Ground floor	Sand & cement screed	£7,150.00						
	PIR insulation	£14,850.00						
	Beam & block floor	£19,800.00						
		£41,800.00						
External walls	Plasterboard w/ skim	£6,370.00						
	Timber battens w/ Isover 32	£4,095.00						
	SmartPly Pro Passiv OSB	£11,830.00						
	Timber studs w/ Isover 32	£18,600.00						
	Medite Vent sheathing board	£9,176.00						
	Breather membrane							
	Ventilated cavity	£248.00						
	Brickwork	£33,480.00						
		£83,799.00						
Party walls	Plasterboard w/ skim	£1,950.00						
	Timber stud w/ Isover 32	£2,730.00						
	Smartply Pro Passiv OSB	£2,535.00						
	Isover 32 filled cavity	£1,365.00						
	Smartply Pro Passiv OSB	£2,535.00						
	Timber stud w/ Isover 32	£2,730.00						
	Plasterboard w/ skim	£1,950.00						
		£15,795.00						
Internal walls	Plasterboard w/ skim	£6,300.00						
	Timber stud w/ Isover 32	£13,500.00						
	Plasterboard w/ skim	£6,300.00						
		£26,100.00						
Intermediate floor	Chipboard floor finish	£2,200.00						
	W. joists w/ mineral wool	£4,840.00						
	Plasterboard w/ skim	£2,640.00						
		£9,680.00						
Roof	Plasterboard w/ skim	£3,520.00						
	Battened service zone	£88.00						
	SmartPly Pro Passiv OSB	£7,150.00						
	Knauf Earthwool 40 insulation	£7,700.00						
	Timber trusses	£8,800.00						
	Ventilated attic	£110.00						
	Tile battens	£2,750.00						
	Concrete tiles	£7,150.00						
	Rainwater goods	£1,680.00						
		£38,948.00						
External doors & windows	Windows PAS 24 DG	£3,930.00	Windows Rehau Artevo DG	£6,467.00	Windows Rehau Artevo TG	£7,469.00	Windows Rehau Artevo TG	£7,469.00
	External doors	£3,000.00	External doors	£3,000.00	External doors	£3,500.00	External doors	£3,500.00
		£6,930.00		**£9,467.00**		**£11,149.00**		**£11,149.00**
Finishes, fixtures & fittings	Internal doors	£10,000.00						
	Floor finishes	£650.00						
	Wall finishes	£8,012.00						
	Ceiling finishes	£2,496.00						
	Kitchen F&F	£9,000.00						
	Wet & bathrooms F&F	£7,000.00						
		£37,158.00						
M&E	General electrical circuit	£13,000.00	General electrical circuit	£13,000.00	General electrical circuit	£13,000.00	General electrical circuit	£13,000.00
	5 kW ASHPs w/ cylinders	£28,500.00	3.5 kW ASHPs w/ cylinders	£25,500.00	3.5 kW ASHPs w/ cylinders	£25,500.00	3.5 kW ASHPs w/ cylinders	£25,500.00
	MEV units (3 per unit)	£2,400.00	EnergiSava 300 MVHR units	£9,800.00	Zehnder ComfoAir 225 units	£13,800.00	Zehnder ComfoAir 225 units	£13,800.00
	PV panels (13 per unit)	£11,190.00	PV panels (8 per unit)	£7,190.00	PV panels (7 per unit)	£6,390.00	PV panels (6 per unit)	£5,590.00
		£55,090.00		**£55,490.00**		**£58,690.00**		**£57,890.00**
Preliminaries (12.5%)		**£41,092.50**		**£41,481.63**		**£42,091.88**		**£41,991.88**
TOTAL		**£369,832.50**	+0.95% uplift	**£373,334.63**	+2.43% uplift	**£378,826.88**	+2.19% uplift	**£377,926.88**

HT 421 cost analysis headlines

- Windows almost double in cost but substantially reduce heat losses
- MVHR most significant CapEx uplift but offsets with reduction in heating demand, regulated demand & PV
- 5 kW reduces to 3.5 kW ASHP
- Lower regulated demand requires less than half the PV provision
- Capital cost uplift limited to < 3%
- Regulated energy savings of > 45%

Critical components of the thermal envelope varied between the operational scenarios are highlighted in green. Note there is no difference between the fabric except for doors and windows: the rest of the fabric is capable of achieving all standards if properly detailed.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue. Only the AD: L Wales (2025) requires a 5 kW ASHP with the remaining scenarios all able to operate with a smaller 3.5 kW ASHP. Smaller heating systems combined with reduced photovoltaic provisions produce CapEX savings that partially offset the cost uplift associated with upgrading from MEV to MVHR.

Heating demand savings assisted by MVHR reduce overall energy consumption by 30-40% and regulated energy demand by 45-55%.

5.2.4 HT 900

This section contains a summary of the operational assessment of **HT 900** with high-level costings followed by detailed cost analyses on page 17. For illustrative drawings of the building and its modelled context, please refer to 5: Appendices.

Operational outputs demonstrates how these semi-detached open market typology performs. Despite similarities with **HT 421** it has increased occupancy courtesy of an additional bedroom and an en suite to Bed 1. While these changes do little to impact space heating demand - it also achieves targets for AECB CarbonLite and LETI, failing MCC - EUI and regulated energy demand are significantly increased.

As the modelled scenarios apply the maximum altitude of strategic development sites and the least favourable building orientation, failing to achieve the threshold by less than 5% is considered acceptable and would not present the same issue on lower altitude sites. At or above the modelled 140m altitude the issue could be overcome by simply optimising orientation with no additional capital expenditure; alternatively, properties could be organised in terraces to significantly reduce space heating demand.

AD: L (Wales) 2025 establishes the baseline for comparisons. Space heating demand is calculated at 99.1 kWh/m²/yr with an EUI of 72.6 kWh/m²/yr of which regulated energy comprises 50.2 kWh/m²/yr.

AECB CarbonLite reduces space heating demand 60% from AD: L (Wales) 2025 and accomplishes a 30% reduction in EUI. Regulated demand reduces almost 45% and therefore 55% of the photovoltaics are required to balance this demand.

MCC's chosen policy position reduces space heating demand almost 75% from AD: L (Wales) 2025 and achieves a 30% reduction in EUI with approximately 50% reduction in regulated energy, requiring 50% of the photovoltaics.

Space heating demand reduces 85% from AD: L (Wales) 2025 to LETI. This achieves more than 35% reduction in EUI and 50% regulated energy demand, requiring fewer than 50% of the photovoltaics.

Cost analysis presents the relative costs apportioned to various building components to achieve the defined operational scenarios. As standardised constructions achieve all levels of operational energy performance the majority of elements attract identical costs with the only differences in Doors & windows, M&E and - resultingly - Preliminaries which are charged at 12.5%.

Improvements to the specification attract an uplift of 1-2% to achieve the operational standards beyond the AD: L (Wales) 2025 baseline. MCC attracts a slightly higher cost than LETI as, while only detailing and build quality separates the specifications, LETI requires fewer photovoltaics to balance energy consumption.

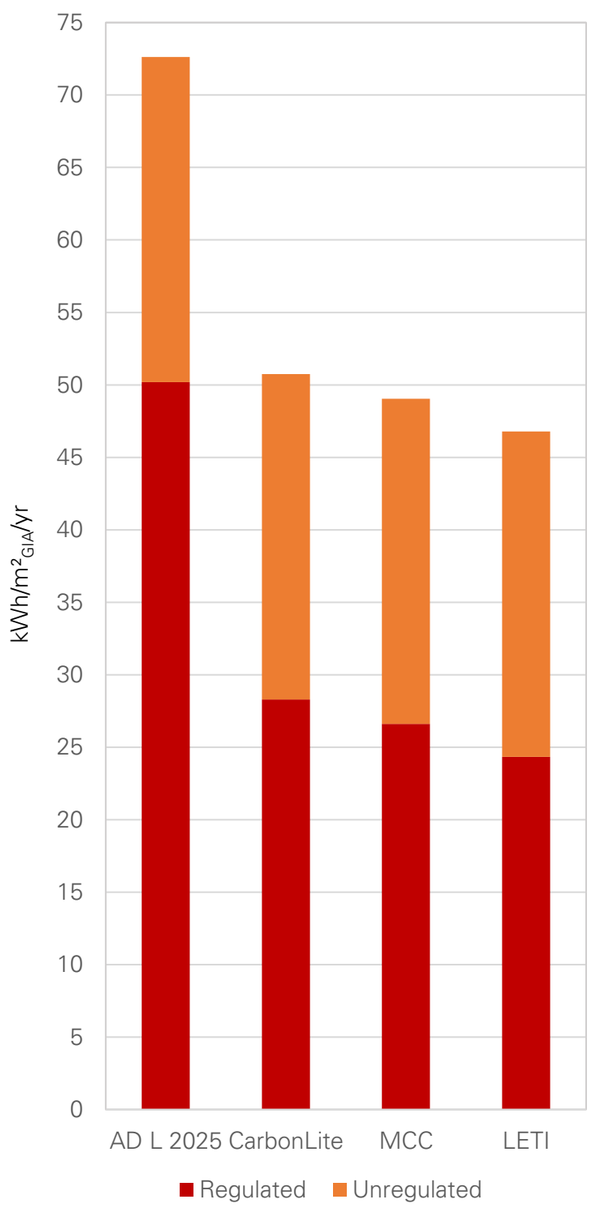
Energy consumption graphed opposite shows how use is split between regulated (heating, domestic hot water, ventilation and lighting) and the unregulated household uses. Regulated energy is represented in red with the already discussed reductions clearly illustrated between the operational scenarios.

As the occupancy and appliances were identical between all modelled scenarios, unregulated energy use - captured in orange - is the same in each instance.

Operational outputs					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	Regulated energy demand	PV per dwelling to meet regulated
1 AD: L (Wales) 2025	99.1 kWh/m²$_{TFA}$/yr	72.6 kWh/m²$_{GIA}$/yr	6,116 kWh/yr	50.2 kWh/m²$_{GIA}$/yr	5.8 kWp
2 AECB CarbonLite	39.4 kWh/m²$_{TFA}$/yr	50.7 kWh/m²$_{GIA}$/yr	4,272 kWh/yr	28.3 kWh/m²$_{GIA}$/yr	3.4 kWp
3 MCC	25.9 kWh/m²$_{TFA}$/yr	49.0 kWh/m²$_{GIA}$/yr	4,130 kWh/yr	26.6 kWh/m²$_{GIA}$/yr	3.0 kWp
4 LETI	15.1 kWh/m²$_{TFA}$/yr	46.8 kWh/m²$_{GIA}$/yr	3,939 kWh/yr	24.3 kWh/m²$_{GIA}$/yr	2.8 kWp

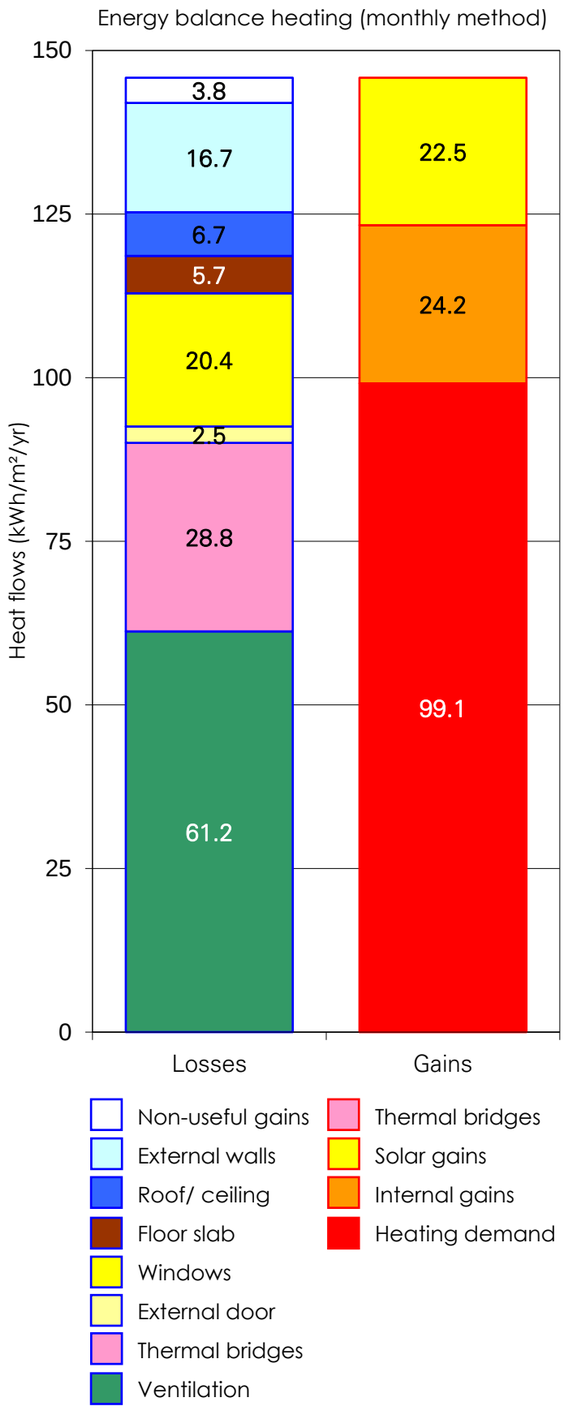
Cost analysis							
Construction	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£13,500.00						
Ground floor	£42,560.00						
External walls	£84,540.00						
Party walls	£16,200.00						
Internal walls	£26,390.00						
Intermediate floor	£10,350.00						
Roof	£38,911.00						
Doors & windows	£7,700.00		£10,276.00		£11,432.00		£11,432.00
FF&F	£39,242.00						
M&E	£57,690.00		£57,290.00		£60,490.00		£59,690.00
Preliminaries	£42,135.38		£42,429.88		£42,974.38		£42,874.38
TOTAL	**£379,218.38**		**£381,868.88**		**£386,769.38**		**£385,869.38**
Cost per unit	£189,609.19		£190,934.44		£193,384.69		£192,934.69
Cost per m²	£2,251.89	+0.70%	£2,267.63	+1.99%	£2,296.73	+1.75%	£2,291.39

Energy consumption

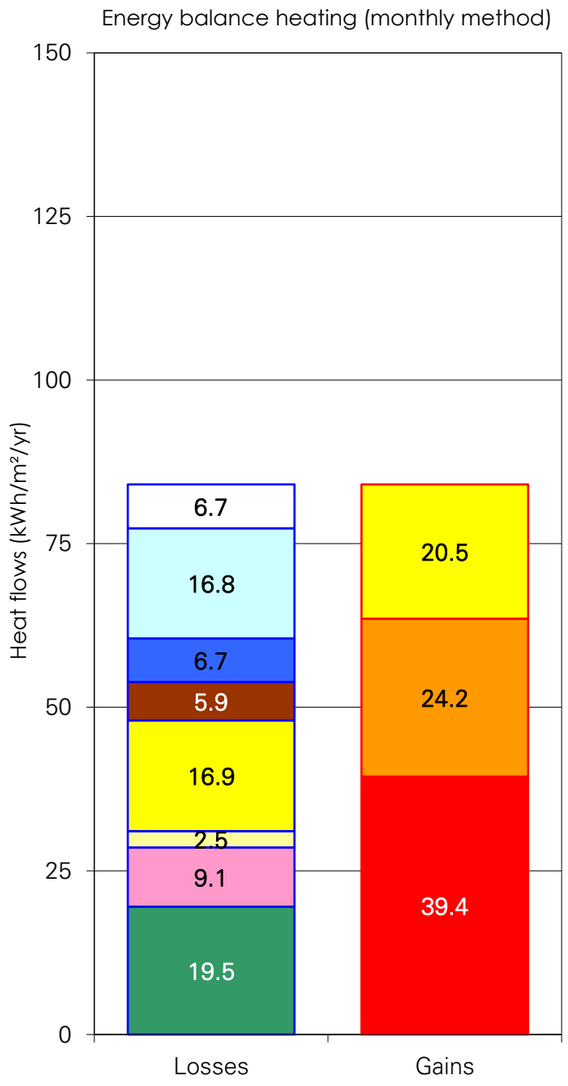


Operational Scenarios

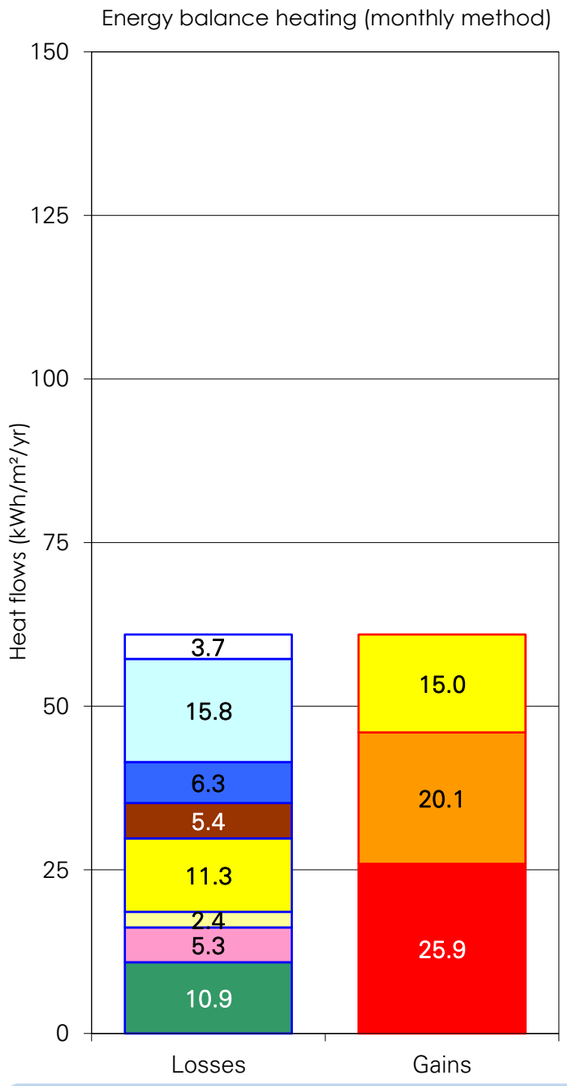
HT 900 - AD: L (Wales) 2025



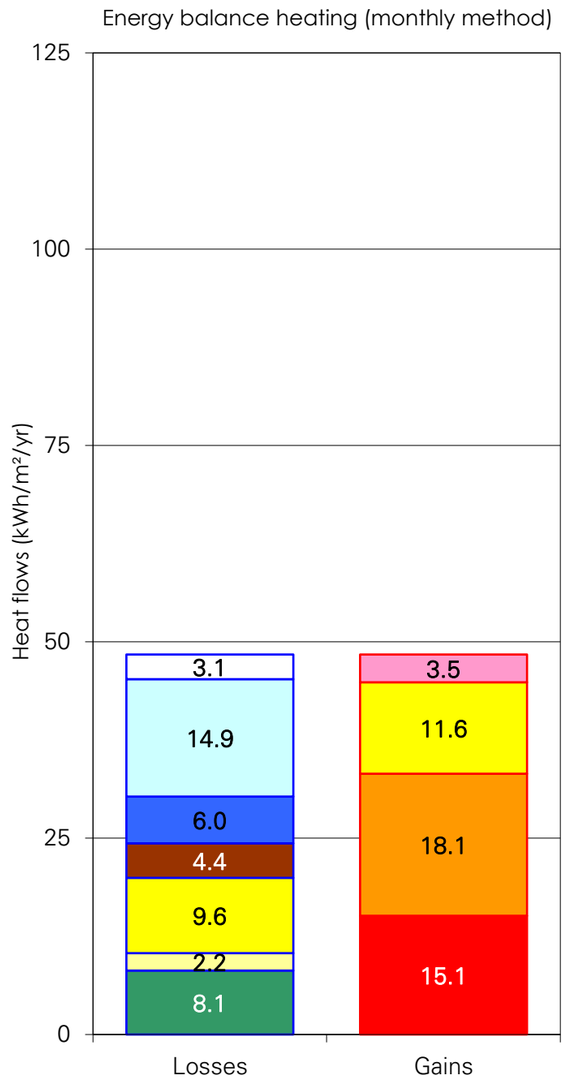
HT 900 - AECB CarbonLite



HT 900 - MCC



HT 900 - 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 2025 electricity unit rate of £0.27 per kWh

Projected Annual Electricity Bills

- AD:L (Wales) 2025 £1,651.32
- AECB CarbonLite £1,153.44
- MCC £1,115.10
- LETI £1,063.53

excludes standing charge & PV offsets

Construction element	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI	
Foundations	Concrete trench fill	£13,500.00						
		£13,500.00						
Ground floor	Sand & cement screed	£7,280.00						
	PIR insulation	£15,120.00						
	Beam & block floor	£21,160.00						
		£42,560.00						
External walls	Plasterboard w/ skim	£6,440.00						
	Timber battens w/ Isover 32	£4,140.00						
	SmartPly Pro Passiv OSB	£11,960.00						
	Timber studs w/ Isover 32	£18,750.00						
	Medite Vent sheathing board	£9,250.00						
	Breather membrane							
	Ventilated cavity	£250.00						
	Brickwork	£33,750.00						
		£84,540.00						
Party walls	Plasterboard w/ skim	£2,000.00						
	Timber stud w/ Isover 32	£2,800.00						
	Smartply Pro Passiv OSB	£2,600.00						
	Isover 32 filled cavity	£1,400.00						
	Smartply Pro Passiv OSB	£2,600.00						
	Timber stud w/ Isover 32	£2,800.00						
	Plasterboard w/ skim	£2,000.00						
		£16,200.00						
Internal walls	Plasterboard w/ skim	£6,370.00						
	Timber stud w/ Isover 32	£13,650.00						
	Plasterboard w/ skim	£6,370.00						
		£26,390.00						
Intermediate floor	Chipboard floor finish	£2,250.00						
	W. joists w/ mineral wool	£4,950.00						
	Plasterboard w/ skim	£3,150.00						
		£10,350.00						
Roof	Plasterboard w/ skim	£3,560.00						
	Battened service zone	£89.00						
	SmartPly Pro Passiv OSB	£7,280.00						
	Knauf Earthwool 40 insulation	£7,840.00						
	Timber trusses	£8,960.00						
	Ventilated attic	£112.00						
	Tile battens	£2,800.00						
	Concrete tiles	£7,280.00						
	Rainwater goods	£990.00						
		£38,911.00						
External doors & windows	Windows PAS 24 DG	£4,200.00	Windows Rehau Artevo DG	£6,776.00	Windows Rehau Artevo TG	£7,032.00	Windows Rehau Artevo TG	£7,032.00
	External doors	£3,500.00	External doors	£3,500.00	External doors	£4,400.00	External doors	£4,400.00
		£7,700.00		**£10,276.00**		**£11,432.00**		**£11,432.00**
Finishes, fixtures & fittings	Internal doors	£10,000.00						
	Floor finishes	£650.00						
	Wall finishes	£8,096.00						
	Ceiling finishes	£2,496.00						
	Kitchen F&F	£11,000.00						
	Wet & bathrooms F&F	£7,000.00						
		£39,242.00						
M&E	General electrical circuit	£14,000.00	General electrical circuit	£14,000.00	General electrical circuit	£14,000.00	General electrical circuit	£14,000.00
	5 kW ASHPs w/ cylinders	£28,500.00	3.5 kW ASHPs w/ cylinders	£25,500.00	3.5 kW ASHPs w/ cylinders	£25,500.00	3.5 kW ASHPs w/ cylinders	£25,500.00
	MEV units (3 per unit)	£2,400.00	EnergiSava 300 MVHR units	£9,800.00	Zehnder ComfoAir 225 units	£13,800.00	Zehnder ComfoAir 225 units	£13,800.00
	PV panels (15 per unit)	£12,790.00	PV panels (9 per unit)	£7,990.00	PV panels (8 per unit)	£7,190.00	PV panels (6 per unit)	£6,390.00
		£57,690.00		**£57,290.00**		**£60,490.00**		**£59,690.00**
Preliminaries (12.5%)		**£42,135.38**		**£42,429.88**		**£42,974.38**		**£42,874.38**
TOTAL		**£379,218.38**	+0.70% uplift	**£381,868.88**	+1.99% uplift	**£386,769.38**	+1.75% uplift	**£385,869.38**

HT 900 cost analysis headlines

- Windows increase in cost c. 150% but substantially reduce heat losses
- MVHR most significant CapEx uplift but offsets with reduction in heating demand, regulated demand & PV
- 5 kW reduces to 3.5 kW ASHP
- Lower regulated demand requires less than half the PV provision
- Capital cost uplift limited to < 2%
- Regulated energy savings of > 45%

Critical components of the thermal envelope varied between the operational scenarios are highlighted in green. Note there is no difference between the fabric except for doors and windows: the rest of the fabric is capable of achieving all standards if properly detailed.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue. Only the AD: L Wales (2025) requires a 5 kW ASHP with the remaining scenarios all able to operate with a smaller 3.5 kW ASHP. Smaller heating systems combined with reduced photovoltaic provisions produce CapEX savings to offset the cost uplift of upgrading MEV to MVHR: this results in a cost saving for M&E between AD: L (Wales) 2025 and AECB CarbonLite.

Heating demand savings assisted by MVHR reduce overall energy consumption by 30-35% and regulated energy demand by 45-50%.

3.1.5 HT 1800

This section contains a summary of the operational assessment of **HT 1800** with high-level costings followed by detailed cost analyses on page 20. For illustrative drawings of the building and its modelled context, please refer to 5: Appendices.

Operational outputs demonstrate the benefits and relative efficiencies gained by larger dwellings - even when detached and featuring appropriately detailed, North-facing feature bay windows - with improved form factor. Applying the standard specification, this typology successfully exceeds the defined space heating demand of each operational scenario.

AD: L (Wales) 2025 establishes the baseline for comparisons. Space heating demand is calculated at 72.8 kWh/m²/yr with an EUI of 56.9 kWh/m²/yr of which regulated energy comprises 39.5 kWh/m²/yr.

AECB CarbonLite reduces space heating demand 55% from AD: L (Wales) 2025 and accomplishes a 30% reduction in EUI. Regulated demand reduces almost 45% and therefore 55% of the photovoltaics are required to balance this demand.

MCC's chosen policy position reduces space heating demand 70% from AD: L (Wales) 2025, achieving an almost 35% reduction in EUI and approximately 50% reduction in regulated energy, requiring 50% of the photovoltaic provisions.

Space heating demand reduces nearly 85% from AD: L (Wales) 2025 to LETI. This achieves more than 35% reduction in EUI and 55% regulated energy demand, requiring 45% of the photovoltaics.

Operational outputs					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	Regulated energy demand	PV per dwelling to meet regulated
1 AD: L (Wales) 2025	72.8 kWh/m²$_{TFA}$/yr	56.9 kWh/m²$_{GIA}$/yr	9,549 kWh/yr	39.5 kWh/m²$_{GIA}$/yr	9.6 kWp
2 AECB CarbonLite	33.7 kWh/m²$_{TFA}$/yr	40.0 kWh/m²$_{GIA}$/yr	6,724 kWh/yr	22.6 kWh/m²$_{GIA}$/yr	5.6 kWp
3 MCC	22.0 kWh/m²$_{TFA}$/yr	38.1 kWh/m²$_{GIA}$/yr	6,401 kWh/yr	20.7 kWh/m²$_{GIA}$/yr	5.0 kWp
4 LETI	12.3 kWh/m²$_{TFA}$/yr	36.1 kWh/m²$_{GIA}$/yr	6,059 kWh/yr	18.7 kWh/m²$_{GIA}$/yr	4.6 kWp

Cost analysis							
Construction	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£12,250.00						
Ground floor	£36,860.00						
External walls	£74,363.00						
Party walls	N/A						
Internal walls	£27,550.00						
Intermediate floor	£8,855.00						
Roof	£49,429.00						
Doors & windows	£8,770.00		£12,518.00		£16,120.00		£16,120.00
FF&F	£36,250.00						
M&E	£33,720.00		£34,895.00		£35,245.00		£34,845.00
Preliminaries	£36,205.88		£36,640.50		£37,134.50		£37,084.50
TOTAL	**£325,852.88**		**£329,764.50**		**£334,210.50**		**£333,760.50**
Cost per unit	£325,852.88		£329,764.50		£334,210.50		£333,760.50
Cost per m²	£1,940.76	+1.20%	£1,964.05	+2.56%	£1,990.53	+2.43%	£1,987.85

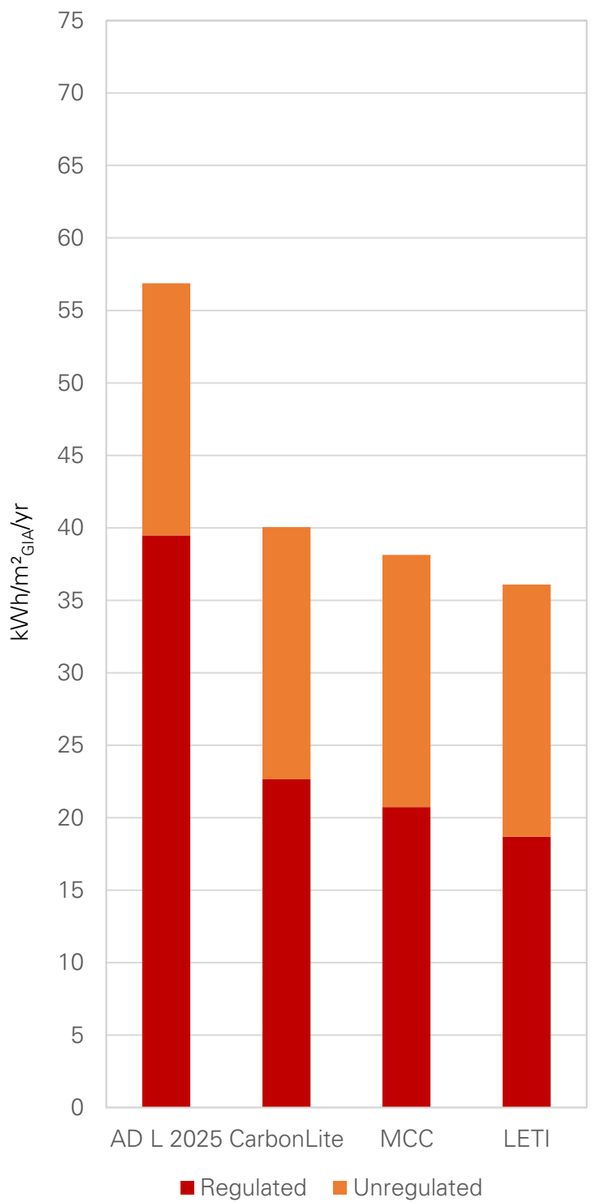
Cost analysis presents the relative costs apportioned to various building components to achieve the defined operational scenarios. As standardised constructions achieve all levels of operational energy performance the majority of elements attract identical costs with the only differences in Doors & windows, M&E and - resultingly - Preliminaries which are charged at 12.5%.

Improvements to the specification attract an uplift of 2-3% to achieve the operational standards beyond the AD: L (Wales) 2025 baseline. MCC attracts a slightly higher cost than LETI as, while only detailing and build quality separates the specifications, LETI requires fewer photovoltaics to balance energy consumption.

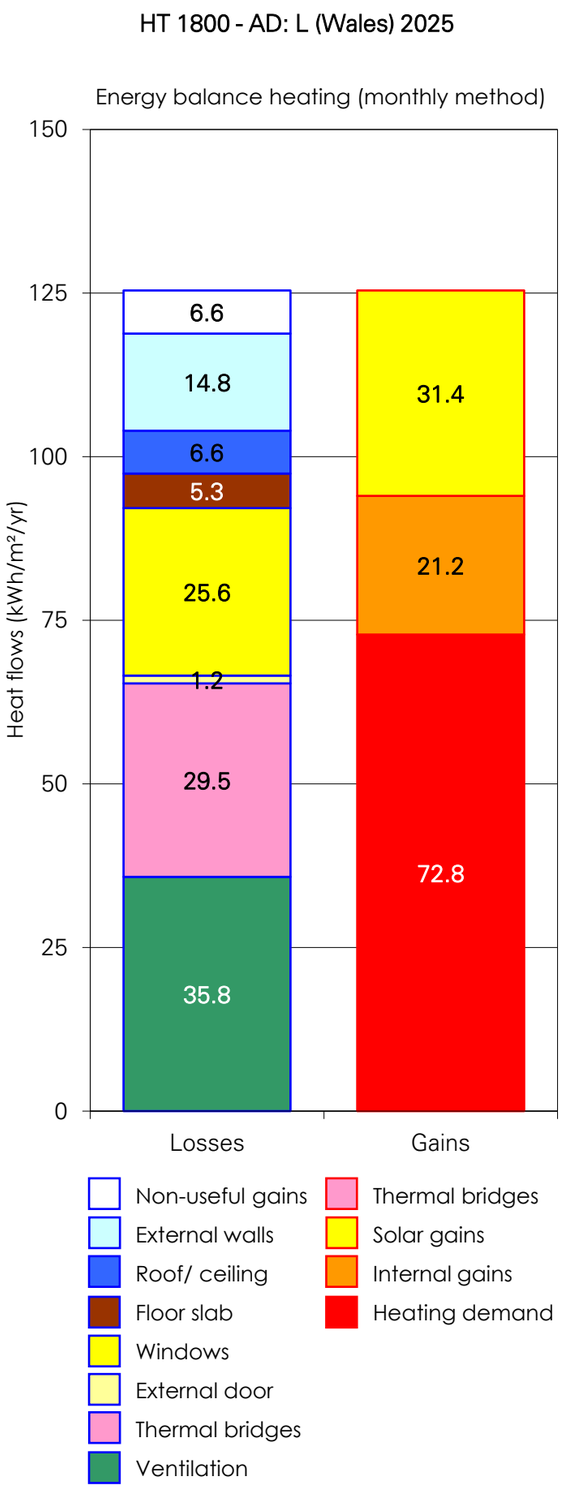
Energy consumption graphed opposite shows how use is split between regulated (heating, domestic hot water, ventilation and lighting) and the unregulated household uses. Regulated energy is represented in red with the already discussed reductions clearly illustrated between the operational scenarios.

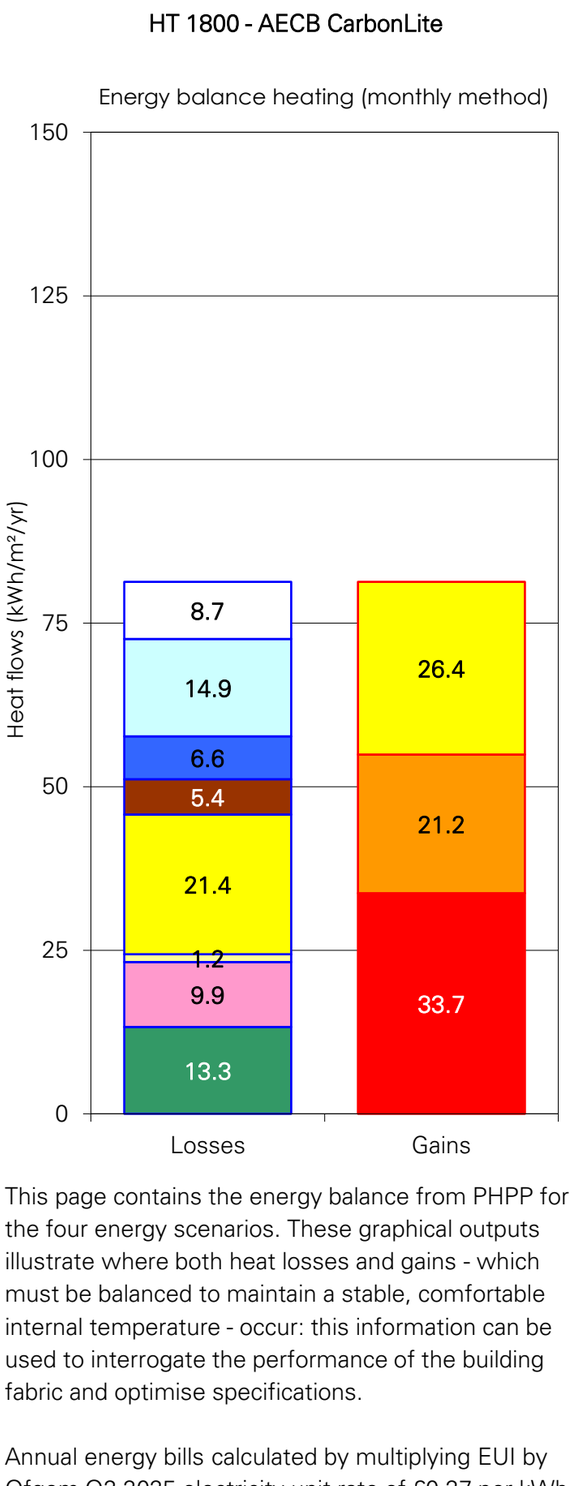
As the occupancy and appliances were identical between all modelled scenarios, unregulated energy use - captured in orange - is the same in each instance.

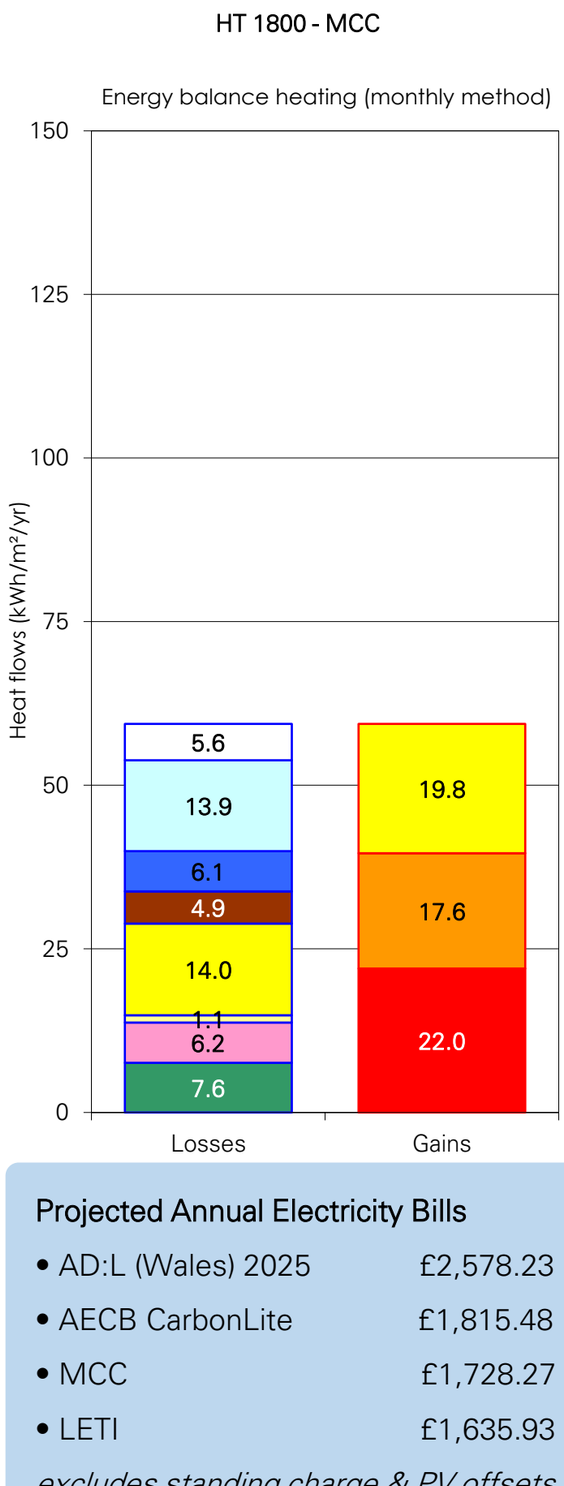
Energy consumption

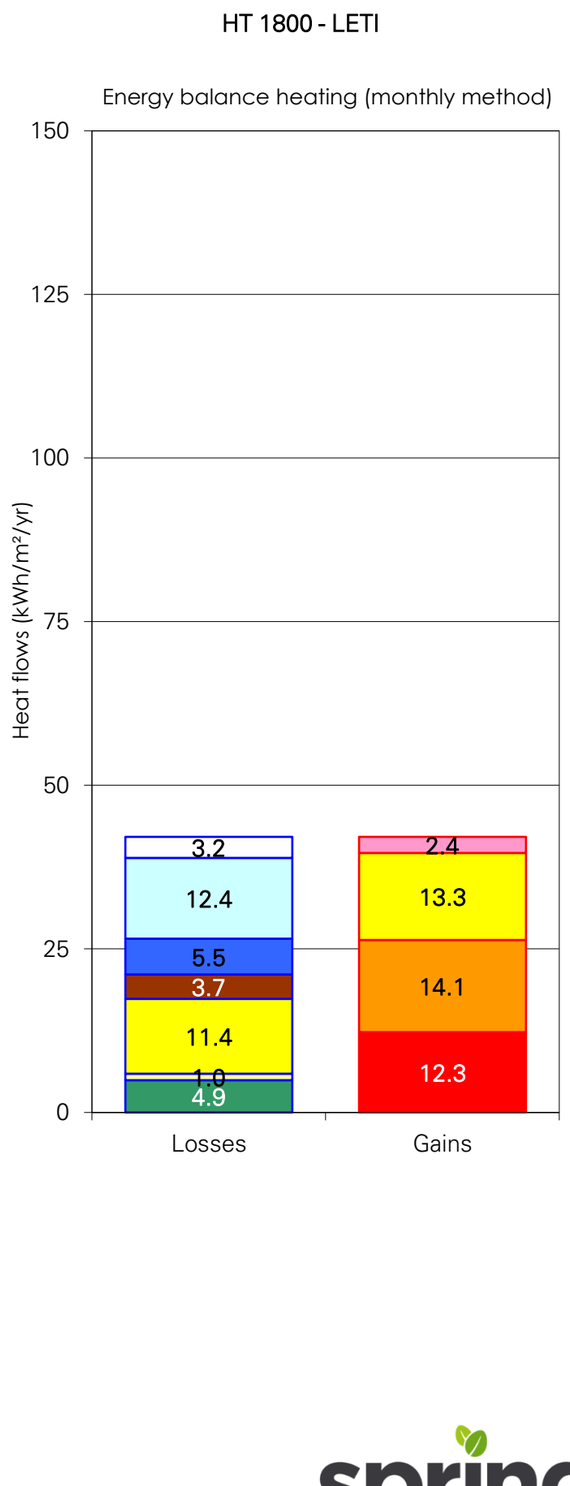


Operational Scenarios









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 2025 electricity unit rate of £0.27 per kWh

Projected Annual Electricity Bills

• AD:L (Wales) 2025	£2,578.23
• AECB CarbonLite	£1,815.48
• MCC	£1,728.27
• LETI	£1,635.93

excludes standing charge & PV offsets

Construction element	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI	
Foundations	Concrete trench fill	£12,250.00						
		£12,250.00						
Ground floor	Sand & cement screed	£6,305.00						
	PIR insulation	£13,095.00						
	Beam & block floor	£17,460.00						
		£36,860.00						
External walls	Plasterboard w/ skim	£6,650.00						
	Timber battens w/ Isover 32	£4,275.00						
	SmartPly Pro Passiv OSB	£12,350.00						
	Timber studs w/ Isover 32	£15,450.00						
	Medite Vent sheathing board	£7,622.00						
	Breather membrane							
	Ventilated cavity	£206.00						
	Brickwork	£27,810.00						
		£74,363.00						
Internal walls	Plasterboard w/ skim	£6,650.00						
	Timber stud w/ Isover 32	£14,250.00						
	Plasterboard w/ skim	£6,650.00						
		£27,550.00						
Intermediate floor	Chipboard floor finish	£1,925.00						
	W. joists w/ mineral wool	£4,235.00						
	Plasterboard w/ skim	£2,695.00						
		£8,855.00						
Roof	Plasterboard w/ skim	£3,080.00						
	Battened service zone	£77.00						
	SmartPly Pro Passiv OSB	£9,555.00						
	Knauf Earthwool 40 insulation	£10,290.00						
	Timber trusses	£11,760.00						
	Ventilated attic	£147.00						
	Tile battens	£3,675.00						
	Concrete tiles	£9,555.00						
	Rainwater goods	£1,290.00						
		£49,429.00						
External doors & windows	Windows PAS 24 DG	£5,270.00	Windows Rehau Artevo DG	£9,018.00	Windows Rehau Artevo TG	£11,720.00	Windows Rehau Artevo TG	£11,720.00
	External doors	£3,500.00	External doors	£3,500.00	External doors	£4,400.00	External doors	£4,400.00
		£8,770.00		**£12,518.00**		**£16,120.00**		**£16,120.00**
Finishes, fixtures & fittings	Internal doors	£7,000.00						
	Floor finishes	£1,040.00						
	Wall finishes	£11,455.00						
	Ceiling finishes	£2,505.00						
	Kitchen & utility F&F	£7,750.00						
	Wet & bathrooms F&F	£6,500.00						
		£36,250.00						
M&E	General electrical circuit	£7,500.00	General electrical circuit	£7,500.00	General electrical circuit	£7,500.00	General electrical circuit	£7,500.00
	10 kW ASHP w/ cylinder	£17,225.00	7 kW ASHP w/ cylinder	£16,500.00	5 kW ASHP w/ cylinder	£14,250.00	5 kW ASHP w/ cylinder	£14,250.00
	MEV units (6 per unit)	£2,400.00	EnergiSava 300 MVHR unit	£4,900.00	Zehnder ComfoAir 225 unit	£7,900.00	Zehnder ComfoAir 225 unit	£7,900.00
	PV panels (24 per unit)	£8,195.00	PV panels (14 per unit)	£5,995.00	PV panels (13 per unit)	£5,595.00	PV panels (12 per unit)	£5,195.00
		£35,320.00		**£34,895.00**		**£35,245.00**		**£34,845.00**
Preliminaries (12.5%)		**£36,205.88**		**£36,640.50**		**£37,134.50**		**£37,084.50**
TOTAL		**£325,852.88**	+1.20% uplift	**£329,764.50**	+2.56% uplift	**£334,210.50**	+2.43% uplift	**£333,760.50**

HT 1800 cost analysis headlines

- Windows almost double in cost but substantially reduce heat losses
- MVHR significant CapEx uplift but offsets with reduction in heating demand, regulated demand & PV
- 10 kW reduces to 7 - 5 kW ASHP
- Lower regulated demand requires less than half the PV provision
- Capital cost uplift limited to < 3%
- Regulated energy savings of c. 55%

Critical components of the thermal envelope varied between the operational scenarios are highlighted in green. Note there is no difference between the fabric except for doors and windows: the rest of the fabric is capable of achieving all standards if properly detailed.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue. Only the AD: L Wales (2025) requires a 10 kW ASHP with the AECB CarbonLite able to reduce to 7 kW and MCC and LETI to 5 kW. Smaller heating systems combined with reduced photovoltaic provisions produce CapEX savings to offset the cost uplift of upgrading MEV to MVHR: this results in a cost saving for M&E between AD: L (Wales) 2025 and all other scenarios.

Heating demand savings assisted by MVHR reduce overall energy consumption by 30-35% and regulated energy demand by 45-55%.

3.1.6 HT 2200

This section contains a summary of the operational assessment of **HT 1800** with high-level costings followed by detailed cost analyses on page 23. For illustrative drawings of the building and its modelled context, please refer to 5: Appendices.

Operational outputs again demonstrate the efficiencies of improved form factor when applying identical fabric and plant specifications. Despite the same occupancy as **HT 1800**, this larger typology exceeds the defined space heating demand of each operational scenario by a more significant margin.

AD: L (Wales) 2025 establishes the baseline for comparisons. Space heating demand is calculated at 60.6 kWh/m²/yr with an EUI of 49.9 kWh/m²/yr of which regulated energy comprises 36.1 kWh/m²/yr.

AECB CarbonLite reduces space heating demand 55% from AD: L (Wales) 2025 and accomplishes a 35% reduction in EUI. Regulated demand reduces almost 50% and therefore 50% of the photovoltaics are required to balance this demand.

Applying the standardised specification for MCC's chosen policy position reduces space heating demand 70% from AD: L (Wales) 2025 and results in almost 30% reduction in EUI and more than 50% reduction in regulated energy, requiring 50% of the photovoltaics.

Space heating demand reduces over 80% from the AD: L (Wales) 2025 scenario to LETI. This achieves more than 40% reduction in EUI and 55% regulated energy demand, requiring 45% of the photovoltaics.

Operational outputs					
Operational scenarios	Space heating demand	Energy use intensity (EUI)	Annual energy use per dwelling	Regulated energy demand	PV per dwelling to meet regulated
1 AD: L (Wales) 2025	60.6 kWh/m²$_{TFA}$/yr	49.9 kWh/m²$_{GIA}$/yr	10,518 kWh/yr	36.1 kWh/m²$_{GIA}$/yr	10.4 kWp
2 AECB CarbonLite	28.0 kWh/m²$_{TFA}$/yr	32.8 kWh/m²$_{GIA}$/yr	6,919 kWh/yr	19.0 kWh/m²$_{GIA}$/yr	5.6 kWp
3 MCC	18.5 kWh/m²$_{TFA}$/yr	31.4 kWh/m²$_{GIA}$/yr	6,616 kWh/yr	17.5 kWh/m²$_{GIA}$/yr	5.0 kWp
4 LETI	11.5 kWh/m²$_{TFA}$/yr	29.8 kWh/m²$_{GIA}$/yr	6,275 kWh/yr	15.9 kWh/m²$_{GIA}$/yr	4.6 kWp

Cost analysis							
Construction	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI
Foundations	£14,250.00						
Ground floor	£41,800.00						
External walls	£89,359.50						
Party walls	N/A						
Internal walls	£39,005.00						
Intermediate floor	£12,075.00						
Roof	£51,997.00						
Doors & windows	£9,470.00		£13,018.00		£17,440.00		£17,440.00
FF&F	£38,625.00						
M&E	£35,620.00		£34,895.00		£35,245.00		£34,845.00
Preliminaries	£41,525.19		£41,904.31		£42,500.81		£42,450.81
TOTAL	**£373,726.69**		**£377,138.81**		**£382,507.31**		**£382,057.31**
Cost per unit	£373,726.69		£377,138.81		£382,507.31		£382,057.31
Cost per m²	£1,773.74	+0.91%	£1,789.93	+2.35%	£1,815.41	+2.23%	£1,813.28

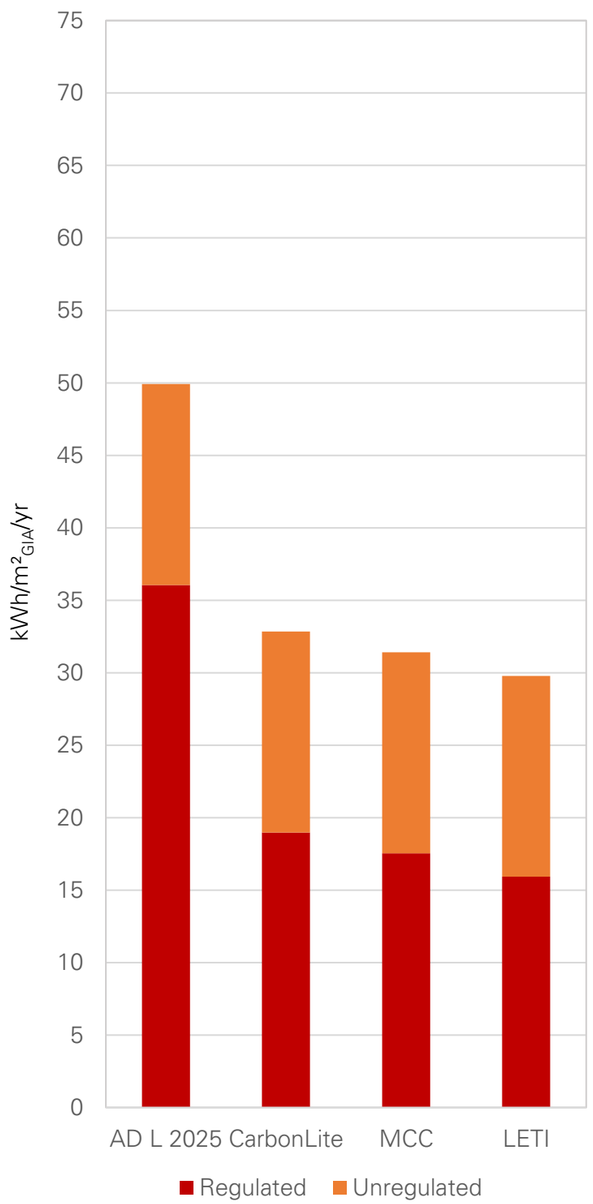
Cost analysis presents the relative costs apportioned to various building components to achieve the defined operational scenarios. As standardised constructions achieve all levels of operational energy performance the majority of elements attract identical costs with the only differences in Doors & windows, M&E and - resultingly - Preliminaries which are charged at 12.5%.

Improvements to the specification attract an uplift of 1-2% to achieve the operational standards beyond the AD: L (Wales) 2025 baseline. MCC attracts a slightly higher cost than LETI as, while only detailing and build quality separates the specifications, LETI requires fewer photovoltaics to balance energy consumption.

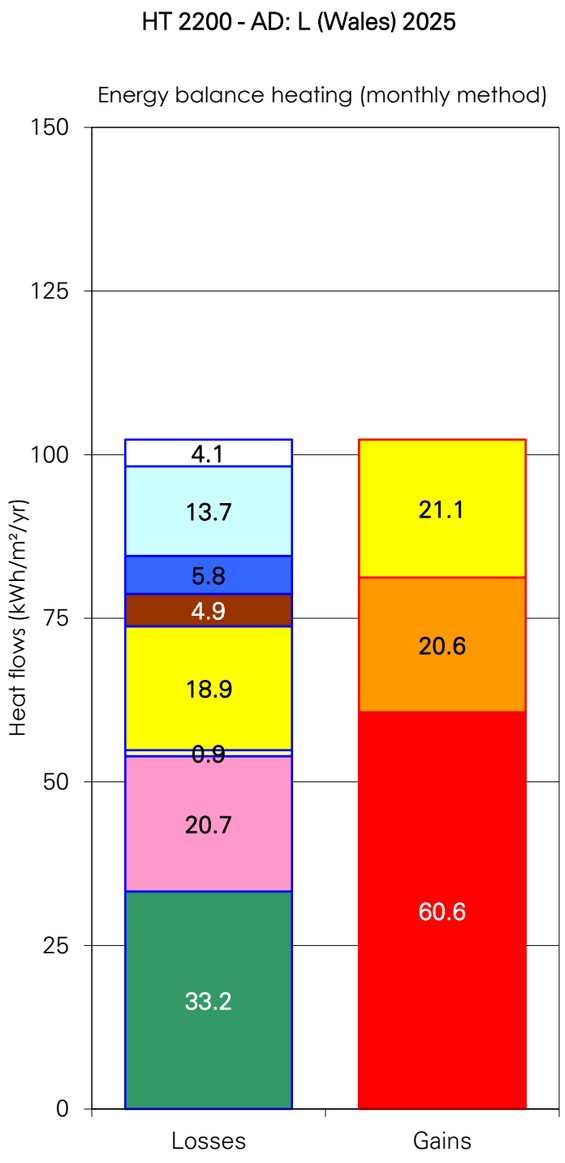
Energy consumption graphed opposite shows how use is split between regulated (heating, domestic hot water, ventilation and lighting) and the unregulated household uses. Regulated energy is represented in red with the already discussed reductions clearly illustrated between the operational scenarios.

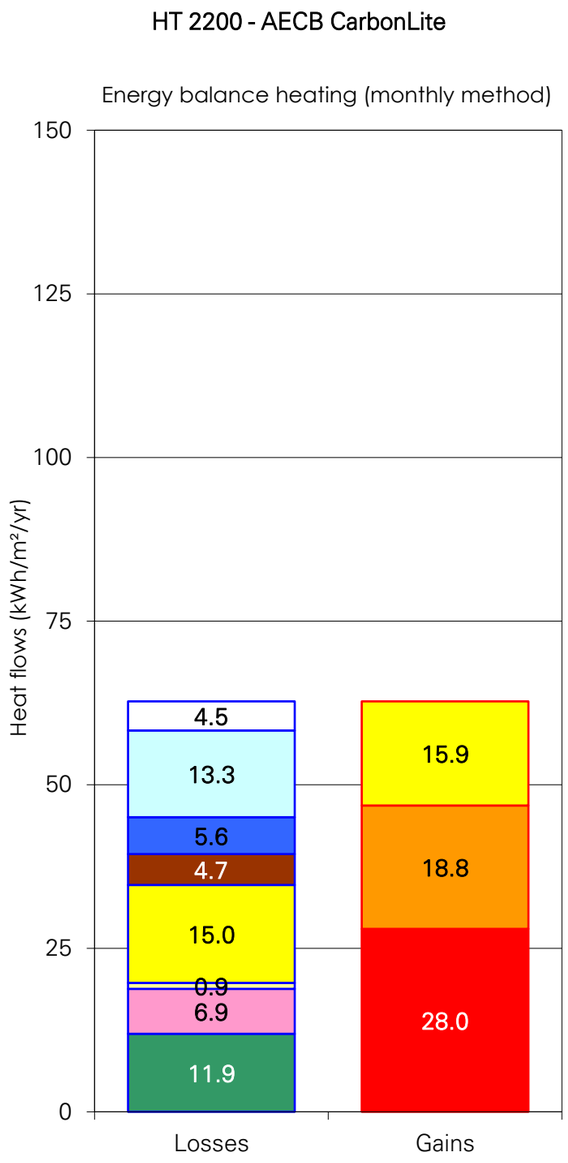
As the occupancy and appliances were identical between all modelled scenarios, unregulated energy use - captured in orange - is the same in each instance.

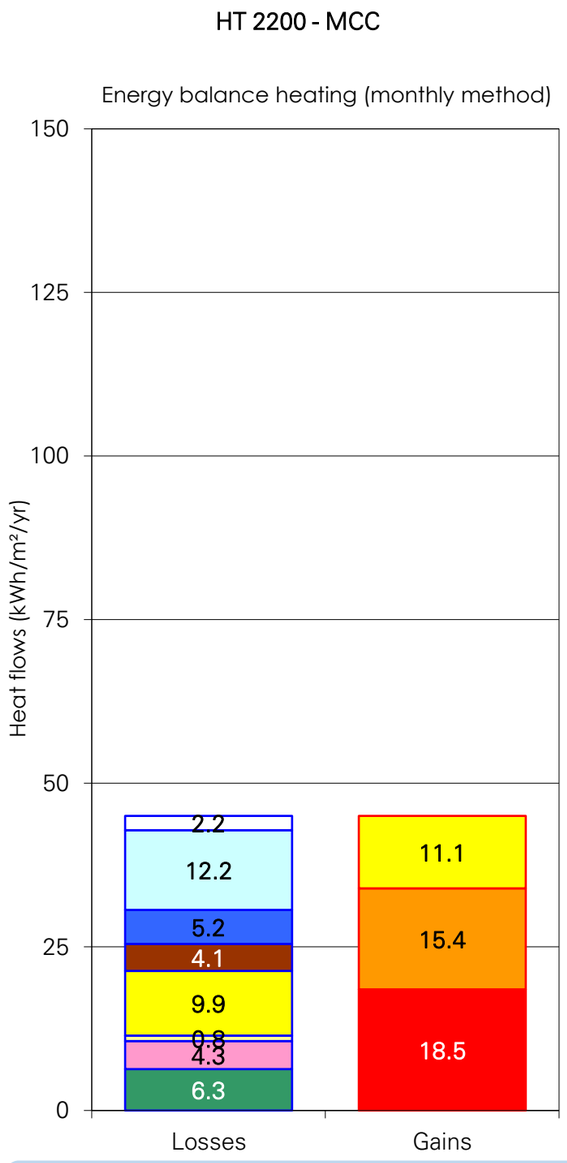
Energy consumption

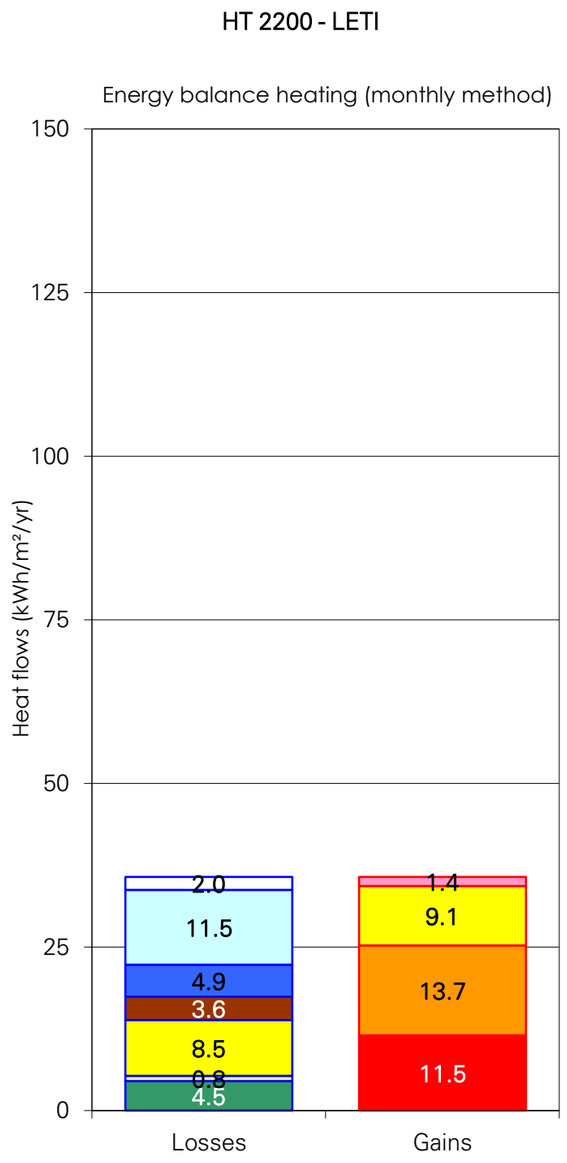


Operational Scenarios









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 2025 electricity unit rate of £0.27 per kWh

Projected Annual Electricity Bills

• AD:L (Wales) 2025	£2,839.86
• AECB CarbonLite	£1,868.13
• MCC	£1,786.32
• LETI	£1,694.25

excludes standing charge & PV offsets

Construction element	1 AD: L (Wales) 2025		2 AECB CarbonLite		3 MCC		4 LETI	
Foundations	Concrete trench fill	£14,250.00						
		£14,250.00						
Ground floor	Sand & cement screed	£7,150.00						
	PIR insulation	£14,850.00						
	Beam & block floor	£19,800.00						
		£41,800.00						
External walls	Plasterboard w/ skim	£6,825.00						
	Timber battens w/ Isover 32	£4,387.50						
	SmartPly Pro Passiv OSB	£12,675.00						
	Timber studs w/ Isover 32	£19,800.00						
	Medite Vent sheathing board	£9,768.00						
	Breather membrane							
	Ventilated cavity	£264.00						
	Brickwork	£35,640.00						
		£89,359.50						
Internal walls	Plasterboard w/ skim	£9,415.00						
	Timber stud w/ Isover 32	£20,175.00						
	Plasterboard w/ skim	£9,415.00						
		£39,005.00						
Intermediate floor	Chipboard floor finish	£2,625.00						
	W. joists w/ mineral wool	£5,775.00						
	Plasterboard w/ skim	£3,675.00						
		£12,075.00						
Roof	Plasterboard w/ skim	£3,320.00						
	Battened service zone	£83.00						
	SmartPly Pro Passiv OSB	£10,010.00						
	Knauf Earthwool 40 insulation	£10,780.00						
	Timber trusses	£12,320.00						
	Ventilated attic	£154.00						
	Tile battens	£3,850.00						
	Concrete tiles	£10,010.00						
	Rainwater goods	£1,470.00						
		£51,997.00						
External doors & windows	Windows PAS 24 DG	£5,970.00	Windows Rehau Artevo DG	£9,518.00	Windows Rehau Artevo TG	£13,040.00	Windows Rehau Artevo TG	£13,040.00
	External doors	£3,500.00	External doors	£3,500.00	External doors	£4,400.00	External doors	£4,400.00
		£9,470.00		**£13,018.00**		**£17,440.00**		**£17,440.00**
Finishes, fixtures & fittings	Internal doors	£7,000.00						
	Floor finishes	£1,040.00						
	Wall finishes	£13,170.00						
	Ceiling finishes	£3,165.00						
	Kitchen & utility F&F	£7,750.00						
	Wet & bathrooms F&F	£6,500.00						
		£38,625.00						
M&E	General electrical circuit	£7,500.00	General electrical circuit	£7,500.00	General electrical circuit	£7,500.00	General electrical circuit	£7,500.00
	10 kW ASHP w/ cylinder	£17,225.00	7 kW ASHP w/ cylinder	£16,500.00	5 kW ASHP w/ cylinder	£14,250.00	5 kW ASHP w/ cylinder	£14,250.00
	MEV units (6 per unit)	£2,400.00	EnergiSava 300 MVHR unit	£4,900.00	Zehnder ComfoAir 225 unit	£7,900.00	Zehnder ComfoAir 225 unit	£7,900.00
	PV panels (26 per unit)	£8,495.00	PV panels (14 per unit)	£5,995.00	PV panels (13 per unit)	£5,595.00	PV panels (12 per unit)	£5,195.00
		£35,620.00		**£34,895.00**		**£35,245.00**		**£34,845.00**
Preliminaries (12.5%)		**£41,525.19**		**£41,904.31**		**£42,500.81**		**£42,450.81**
TOTAL		**£373,726.69**	+0.91% uplift	**£377,138.81**	+2.35% uplift	**£382,507.31**	+2.23% uplift	**£382,057.31**

HT 2200 cost analysis headlines

- Windows almost double in cost but substantially reduce heat losses
- MVHR significant CapEx uplift but offsets with reduction in heating demand, regulated demand & PV
- 10 kW reduces to 7 - 5 kW ASHP
- Lower regulated demand requires less than half the PV provision
- Capital cost uplift limited to < 3%
- Regulated energy savings of c. 50%

Critical components of the thermal envelope varied between the operational scenarios are highlighted in green. Note there is no difference between the fabric except for doors and windows: the rest of the fabric is capable of achieving all standards if properly detailed.

Critical MEP elements that alter between the costed operational scenarios are highlighted in blue. Only the AD: L Wales (2025) requires a 10 kW ASHP with the AECB CarbonLite able to reduce to 7 kW and MCC and LETI to 5 kW. Smaller heating systems combined with reduced photovoltaic provisions produce CapEX savings to offset the cost uplift of upgrading MEV to MVHR: this results in a cost saving for M&E between AD: L (Wales) 2025 and all other scenarios.

Heating demand savings assisted by MVHR reduce overall energy consumption by 35-40% and regulated energy demand by 50-55%.

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 regulated energy and reducing the size of heating systems. These cost savings may mean the most economical housing product leverages the highest feasible level of performance, marketing this as a sales feature to realise higher property values and improve loan affordability, expanding the market.

In the case of larger or otherwise optimised buildings (apartment and terraced typologies) targeting heating demand or EUI based performance metrics could justify potential reductions in insulation thicknesses. The resulting material efficiencies would further benefit project costs.

This assessment has focused on a range of residential typologies modelled on a nominal site at 140m altitude, applying typical design responses in an East-West orientation to demonstrate the technical feasibility of meeting regulated energy demand with on-site renewable generation. Further optimisations - including but not limited to improved form factor, orientation and fenestration design - could reach this goal more efficiently, realising further 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 30-60% available applying these improvements
- Reduced EUI requires 40-50% fewer PV panels to balance regulated energy
- Heat pumps reduce energy required for heating & hot water demand to < 25% of the direct electric equivalent

Headlines for MCC policy position

- Space heating demand reduced 70% upgrading **AD: L (Wales) 2025** to **MCC**
- EUI & annual energy consumption reduced > 30% by adopting **MCC**
- Regulated energy & PV provisions reduced > 50% by adopting **MCC**
- Standard specifications developed to demonstrate technical feasibility of space heating demand targets despite challenging altitude & orientation of modelled scenarios

Headlines for cost analysis

- Window upgrades £1.25 - 8k per unit
- MVHR upgrades £4 - 5k per unit
- Heating demand reductions > 80%
- EUI & CO_2e reductions 30-60%
- Regulated energy reductions 50-60%
- 40-50% fewer PV panels required
- Fewer PV panels & smaller heating systems generate CapEx savings
- CapEx uplift limited to 0.70 – 2.73% upgrading beyond AD: L (Wales) 2025
- Bespoke specifications for otherwise optimised housing typologies could produce additional CapEx savings
- Energy efficiency is recognised as contributing to desirability, increased and market-resilient property prices
- Energy efficiency can be used as a lever to access lower interest finance products & lower insurance premiums for developers & homeowners

HT 211	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI	
TOTAL	**£1,106.674.88**	**£1,136,640.38**		**£1,154,611.13**		**£1,152,586.13**	
Cost per unit	£122,963.88	£126,293.38		£128,290.13		£128,065.13	
Cost per m²	£2,182.79	+2.71%	£2,241.89	+4.33%	£2,277.34	+4.15%	£2,273.35
HT 212	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI	
TOTAL	**£528,839.44**	**£533,469.94**		**£543,261.94**		**£543,261.94**	
Cost per unit	£132,209.86	£133,367.48		£135,815.48		£135,815.48	
Cost per m²	£2,350.40	+0.88%	£2,370.98	+2.73%	£2,414.50	+2.73%	£2,414.50
HT 421	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI	
TOTAL	**£369,832.50**	**£373,334.63**		**£378,826.88**		**£377,926.88**	
Cost per unit	£184,916.25	£186,667.31		£189,413.44		£188,963.44	
Cost per m²	£2,222.55	+0.95%	£2,243.60	+2.43%	£2,276.60	+2.19%	£2,271.20
HT 900	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI	
TOTAL	**£379,218.38**	**£381,868.88**		**£386,769.38**		**£385,869.38**	
Cost per unit	£189,609.19	£190,934.44		£193,384.69		£192,934.69	
Cost per m²	£2,251.89	+0.70%	£2,267.63	+1.99%	£2,296.73	+1.75%	£2,291.39
HT 1800	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI	
TOTAL	**£325,852.88**	**£329,764.50**		**£334,210.50**		**£333,760.50**	
Cost per unit	£325,852.88	£329,764.50		£334,210.50		£333,760.50	
Cost per m²	£1,940.76	+1.20%	£1,964.05	+2.56%	£1,990.53	+2.43%	£1,987.85
HT 2200	1 AD: L (Wales) 2025	2 AECB CarbonLite		3 MCC		4 LETI	
TOTAL	**£373,726.69**	**£377,138.81**		**£382,507.31**		**£382,057.31**	
Cost per unit	£373,726.69	£377,138.81		£382,507.31		£382,057.31	
Cost per m²	£1,773.74	+0.91%	£1,789.93	+2.35%	£1,815.41	+2.23%	£1,813.28

Section 5: Appendices

5.1 Building Typologies

5.1.1 Residential

Refer to drawings:

2774-211(02)100 - HT 211 Notional Site Layout
2774-211(02)101 - HT 211 Notional Street Elevation
2774-211(02)200 - HT 211 GF Plan
2774-211(02)201 - HT 211 1F Plan
2774-211(02)202 - HT 211 2F Plan
2774-211(02)300 - HT 211 Elevations
2774-211(02)301 - HT 211 Elevations

2774-212(02)100 - HT 212 Notional Site Layout
2774-212(02)200 - HT 212 Floor Plans
2774-212(02)300 - HT 212 Elevations

2774-421(02)100 - HT 421 Notional Site Layout
2774-421(02)200 - HT 421 Floor Plans
2774-421(02)300 - HT 421 Elevations

2774-900(02)100 - HT 900 Notional Site Layout
2774-900(02)200 - HT 900 Floor Plans
2774-900(02)300 - HT 900 Elevations

2774-1800(02)100 - HT 1800 Notional Site Layout
2774-1800(02)200 - HT 1800 Floor Plans
2774-1800(02)300 - HT 1800 Elevations

2774-2200(02)100 - HT 2200 Notional Site Layout
2774-2200(02)200 - HT 2200 Floor Plans
2774-2200(02)300 - HT 2200 Elevations

Unit 2
Chapel Barns
Merthyr Mawr
Bridgend
CF32 0LS

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

Architecture
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