Whole Life Carbon Assessment

The Lodge
178 Bearwood Road
Wokingham
RG41 4SH

Contents

0 Introduction

According to the Green Construction Board, the built environment sector is currently responsible for 35-40% of the UK's total greenhouse gas (GHG) emissions (Sturgis, 2017) and for over 30% of global emissions (IPCC, 2014; Huovila et al., 2009). GHG's are used and produced throughout a building's lifespan, and for analysis purposes are often categorised as construction, operation, and end-of-life emissions. The UK's Approved Document L works to guide the reduction of operational emissions; however, operational CO_2e is typically responsible for only 20% of a building's emissions. The more impactful, and relatively unregulated construction process is often responsible for circa 50% of a buildings GHG emissions (Sturgis and Papakosta, 2017), and accordingly should take more precedent in sustainable design and regulation. In addition to quantifying the emissions associated with the construction and operational phases of a building, the end-of-life stage should be considered as there are GHG emissions associated with the transportation, recycling, and disposal of building materials.
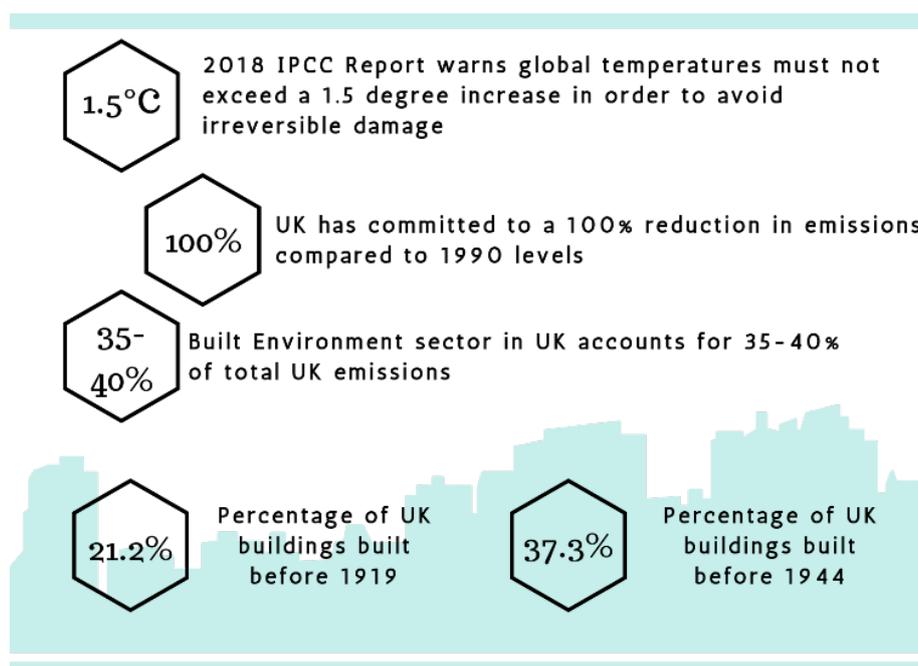

Figure 1. Key statistics relevant to the built environment and climate change mitigation

1 Case for Replacement

The existing dwelling is piecemeal in design, comprising of a ground and lower ground floor. All constructed off an un-insulated and cracked concrete slab, unfit for purpose with heavy rain inciting water rising into the utility. The superstructure is timber, with poorly performing, un-insulated timber clad walls. The inadequate detailing, lack of insulation and poor airtightness all contribute to a poorly performing dwelling.

Refurbishment of the existing building has been considered to increase the energy performance in accordance with Approved Document L.

Table 4.3 Limiting U-values for existing elements in existing dwellings		
Element	U-value[1] W/(m²·K)	
	(a) Threshold	(b) Improved
Roof[2][3][4]	0.35	0.16
Wall – cavity insulation[2][5]	0.70	0.55
Wall – internal or external insulation[2][6]	0.70	0.30
Floor[7][8]	0.70	0.25

Figure 2. Limiting U-values for existing elements in existing dwellings

The above table states the required U-values for the improvement of an existing dwelling, and while these are achievable, limitations begin to arise due to the existing provisions and construction as explored below.

Polymer based insulations could be used between the internal studwork; however, the existing studwork is limited in depth, making achieving contemporary U-Value requirements impractical. To achieve contemporary standards, the internal studs to be extended, in principle, this would result in an entirely new wall.

External insulation could be considered, but to maintain breathability a lower performant, breathable insulation will be required, taking up significant space. Retro-fitting external insulation will also result in a non-continuous thermal envelope, causing unwanted loss of heat.

Another major loss in thermal performance is often due to poor air-tightness, an incredibly hard element to tackle in a retro-fit. Therefore, any insulation improvements not only come with their own limitations as compared to a new dwelling, but unwanted thermal loss will be inevitable.

The water in the existing house is heated by electric heater with the primary heating in the house being a ducted log burning stove in the living room. This arrangement causes the additional use of inefficient electric space heaters in the bathroom, along with an electric towel rail year-round, with free standing electrical radiators being utilised during winter.

Domestic heating in existing buildings usually accounts for 64% of total the primary energy demand, however the need to use electric appliances to provide additional heat sources significantly increases this figure.

Therefore, the decision has been made to design a new sustainable building with U-values exceeding current regulations, thermal bridge free detailing and improved airtightness.

2 Proposal

2.1 Lifetime Carbon Analysis Methodology

2.1.1 Databases Suitable for Application to UK buildings Produce a Building LCA

- the Inventory of Carbon and Energy (ICE) database (Circular Ecology, 2019),
- the Green Guide (BRE Group, 2019)
- BRE Global Methodology for The Environmental Assessment Of Buildings Using EN 15978:2011
- WRAP Embodied Carbon database (WRAP, 2019a; WRAP, 2019b)
- BS EN 15978:2011 Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method
- BS EN 15804:2012+A1:2013 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products
- EN 15203 Energy performance of buildings – Overall energy use, CO2 emissions and definition of energy ratings
- CIBSE Guide M. Maintenance engineering and management
- CIBSE TM54: 2022 Evaluating operational energy use at the design stage
- IStructE A brief guide to calculating embodied carbon
- NRM3: Order of cost estimating and cost planning for building maintenance works
- RICS guidance note 2nd edition October 2021
- PHPP Passive House Planning Package Version 9.6a

These databases/tools were reviewed against the following criteria: source (where the data was extracted from), scope (how many materials are included), accessibility (ease of use), and update frequency (how often the data is updated to make sure it is accurate).

The life cycle analysis was conducted of the below elements through stages A1-C4 in accordance with RICS guidance:

Demolition and Enabling Works

Substructure
Foundations

Superstructure
Floors
Roof

External Walls
Internal Walls
External Fenestration
Finishes, Wall, Floor Ceiling (accounted in relevant element)

Fittings, furnishings, and equipment (FF&E)

Building Services/MEP

Sequestered Carbon

The data was sourced primarily from manufacturer specific EPD's, and where relevant an extensive literature review carried out by the developers of ICE.

2.1.2 Reference Study Period (RSP)

RSP is based on the principles outlined in EN 15978:2011 and accounts for 60 years for domestic projects (BREEAM 2014 New Construction – Mat 01 Life cycle impacts; LEED v.4).

2.1.3 Life Cycle Stages

Whole life embodied carbon calculations involve considering all life cycle stages of a project, from raw material extraction, product manufacturing, transport, and installation on site through to the operation, maintenance, and eventual material disposal. This section refers to EN 15978; 7.4. It also considers the separately reported future potential for recovery, reuse and/or recycling. EN 15978 introduces a modular approach to a built asset's life cycle, breaking it down into different stages. Module D (Reuse, recycling etc.) are reported separately to modules A-C, and as they are independent values, module D is optional, with A-C representing a cradle to grave analysis.
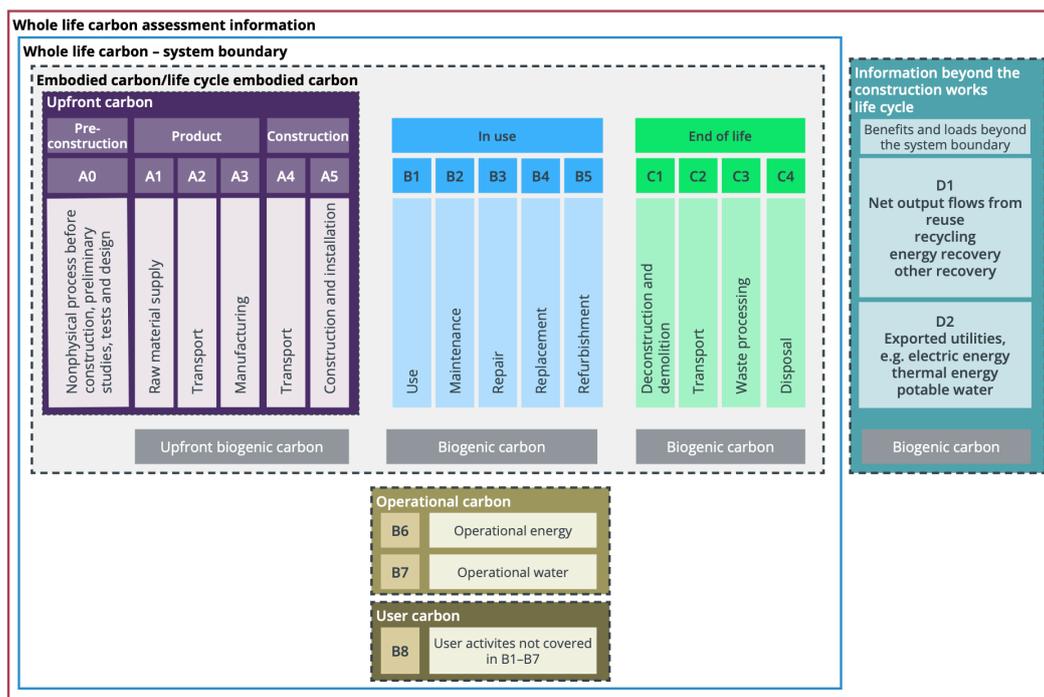
Figure 3. Life cycle stages (RICS, Whole Life Carbon Assessment for the Built Environment, 2024)

Whole life carbon, reported as kilograms of carbon equivalent per m² of gross internal area (kgCO2e/m²), includes stages [A], [B] & [C]; with module [D] and Sequestration to be reported separately.

Embodied carbon was calculated for each construction element, with the total divided by the project GIA 288m².

Due to the project currently being in an early design phase, EPD data was used for the primary fabric, but some assumptions regarding the more detailed elements such as M&E, fit out etc. had to be made in accordance with RICS guidance for residential dwellings to achieve an accurate result.
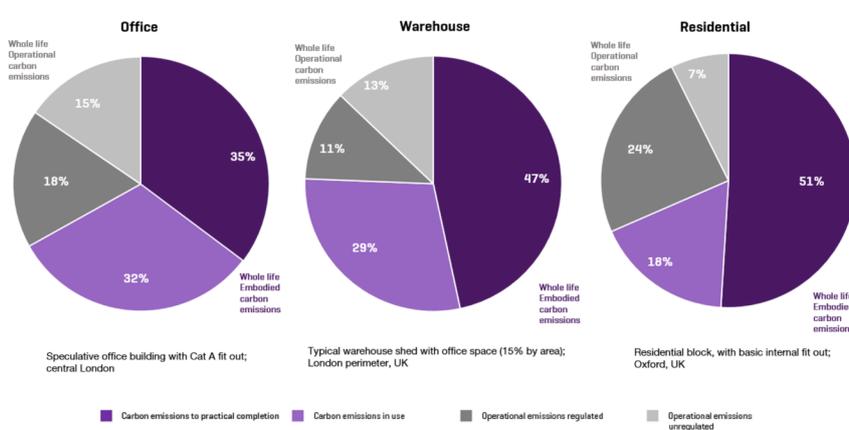

Figure 4. Total whole life carbon emissions break down for different types of buildings

2.2 Lifetime Carbon Analysis

2.2.1 Enabling deconstruction and demolition

This section refers to EN 15978; 7.4.5.2 and 8.7.2. Deconstruction should cover all site-based activities required to dismantle, deconstruct and/or demolish the built asset being assessed. The carbon emissions arising from any on or off-site deconstruction and demolition activities, including any energy consumption for site accommodation and plant use, must be considered in [A5.1]. As per RICS guidance (P.81) an average rate of 35 kgCO2e/m2 GIA is to be used in the absence of more specific information.

Demolition of the existing building:

Existing building GIA=101.45m^2

35 kgCO2e/m2 x 101.45m^2 = 3551 kgCO$_2$e

2.2.2 Substructure

641 - Bearwood																
Foundation																
		Foundation Type 1 (House)														
		Material	Linear Infill (m infil per m) (m)	Height (Y axis) (m)	Density (kg/m^3)	Mass (kg/m)	Embodied Carbon per kg (kgCO$_2$e/kg)	Embodied kgCO$_2$e/m	Linear distance of Foundation (m)		Mass (kg)	Carbon (kgCO2e)	Total Foundation CE (kg)	Total CE per m^2	
Internal									73.25						
		Gen III Trench Fill (600x1000)	0.6	1	2200	1320	0.070044	92.45808			96690	6772.55436	11442.6814	156.21408	
		Reinforced Concrete	0.6	1	2300	1380	0.0462	63.756			101085	4670.127			
External															

Figure 5. Embodied carbon in foundations.

2.2.3 Superstructure

641 - Bearwood															
Floors															
		Ground Floor Type 1 (Weighted Floor Finish)													
		Material	Linear Infill (m infil per m) (m)	Height (Y axis) (m)	Density (kg/m^3)	Mass (kg/m^2)	Embodied Carbon per kg (kgCO$_2$e/kg)	Embodied kgCO$_2$e/m	Area (m^2)	Mass (kg)	Carbon (kgCO2e)	Total Slab Carbon	Slab Carbon per m^2	Total Carbon	Total Carbon per m^2
Internal									200						
		50mm flowScreed	1	0.05	2100	105	0.161	16.905		21000	3381	16203.446	81.01723	18863.4073	56.30867836
		150 insulation expanded polystyrene	1	0.15	25	3.75	3.29	12.3375		750	2467.5				
		140 mm GENIII 16/20 Mpa	1	0.14	2300	322	0.11674	37.59028		64400	7518.056				
		Steel Mesh	1	1	2.2	2.2	1.99	4.378		440	875.6				
		100mm Compacted Hardcore Type 1 Quarried	1	0.1	2400	240	0.00748	1.7952		48000	359.04				
External															
		25mm Floor Finish	1	0.025	650	16.25	0.493	8.01125		3250	1602.25				
		First Floor Type 1 (Weighted Floor Finish)													
		Material	Linear Infill (m infil per m) (m)	Height (Y axis) (m)	Density (kg/m^3)	Mass (kg/m^2)	Embodied Carbon per kg (kgCO$_2$e/kg)	Embodied kgCO$_2$e/m	Area (m^2)	Mass (kg)	Carbon (kgCO2e)	Total Floor Carbon	Floor Carbon per m^2		
Internal									135						
		22mm T&G	1	0.022	660	14.52	-0.971857576	-14.111372		1960.2	-1905.0352	2585.89125	19.15475		
		253x72mm Posi Joist @ 400 ctrs	0.162	0.253	281	11.517066	-2.34	-26.94993444		1554.80391	-3638.2411				
		200mm Acoustic Rockwool	0.95	0.2	25	4.75	1.371	6.51225		641.25	879.15375				
		12.5mm Plasterboard	1	0.0125	950	11.875	0.39	4.63125		1603.125	625.21875				
External															
		25mm Floor Finish	1	0.025	650	16.25	0.493	8.01125		2193.75	1081.51875				
		Finishes				Embodied Carbon per m^2 (for single coat) (kgCO$_2$e/kg)			Area (m^2)		Carbon (kgCO2e)	Total Finish Carbon	Finish Carbon per m^2		
									135						
		Paint (2 coats)				0.161					43.47	74.07	0.2571875		
		Plaster				0.226666667					30.6				

Figure 6. Embodied carbon in floor construction (Ground floor and First floor)

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External Walls

External Wall Type 1 (Brick Clad)

Material	Linear Infill (m infil per m) (m)	Depth (X axis) (m)	Density (kg/m³)	Mass (kg/m²)	Embodied Carbon per kg (kgCO₂e/kg)	Embodied kgCO₂e/m	Area (m²)	Mass (kg)	Carbon (kgCO2e)	Total Wall Type 1 Carbon	Wall Type 1 Carbon per m²	Total Carbon	Total Carbon per m²	Sequester Mass	Co2 Sequestered
							139								
12.5mm Plasterboard	1	0.0125	950	11.875	0.39	-4.63125		1650.625	643.74375	1607.15041	11.5622332	5125.26354	17.2567796	16804.992	-25104.82968
50x50 Batten 600 ctrs	0.083	0.05	480	1.992	-1.29	-2.56968		276.888	-357.18552						
Actis H Control Hybrid (45mm)	0.875	0.045	9.5	0.3740625	4.063	1.519815638		51.9940875	211.254415						
200x50mm C24 Stud at 400 ctrs	0.125	0.2	480	12	-1.29	-15.48		1668	-2151.72						
170mm Actis Hybris between Studs	0.875	0.17	9.13	1.3580875	2.283	3.100513763		188.774163	430.071413						
15mm OSB Sheeting	1	0.015	1300	19.5	-1.05	-20.475		2710.5	-2846.025						
Actis Boost R Hybrid (35mm)	0.875	0.035	18.57	0.56870625	4.063	2.310635494		79.0501688	321.190036						
25x50mm Vertical Batten at 400 ctrs	0.125	0.025	480	1.5	-1.29	-1.935		208.5	-268.965						
85mm Cavity	1	0	0	0	0	0		0	0						
Pirrouet*: carbon-negative facing bricks	1	0.05	900	45	-2.06	-92.7		6255	-12885.3						

External Wall Type 2 (Clay Tile)

Material	Linear Infill (m infil per m) (m)	Depth (X axis) (m)	Density (kg/m³)	Mass (kg/m²)	Embodied Carbon per kg (kgCO₂e/kg)	Embodied kgCO₂e/m	Area (m²)	Mass (kg)	Carbon (kgCO2e)	Total Wall Type 2 Carbon	Wall Carbon per m²
							158				
12.5mm Plasterboard	1	0.0125	950	11.875	0.39	4.63125		1876.25	731.7375	3355.15913	21.2351844
50x50 Batten 600 ctrs	0.083	0.05	480	1.992	-1.29	-2.56968		314.736	-406.00944		
Actis H Control Hybrid (45mm)	0.917	0.045	9.5	0.3920175	4.063	1.592767103		61.938765	251.657202		
200x50mm C24 Stud at 400 ctrs	0.125	0.2	480	12	-1.29	-15.48		1896	-2445.84		
170mm Actis Hybris between Studs	0.875	0.17	9.13	1.3580875	2.283	3.100513763		214.577825	489.881174		
15mm OSB Sheeting	1	0.015	1300	19.5	-1.05	-20.475		3081	-3235.05		
Actis Boost R Hybrid (35mm)	0.875	0.035	18.57	0.56870625	4.063	2.310635494		89.8555875	365.063252		
25x50mm Vertical Batten at 400 ctrs	0.125	0.025	480	1.5	-1.29	-1.935		237	-305.73		
25x25mm Counter Battens at 300mm ctrs	0.083	0.025	480	0.996	-1.29	-1.28484		157.368	-203.00472		
Clay Tiles	1	0.01	2000	20	0.48	9.6		3160	1516.8		

Finishes	Embodied Carbon per m² (for single coat) (kgCO₂e/kg)	Area (m²)	Carbon (kgCO2e)	Total Finish Carbon	Finish Carbon per m²
		297			
Paint (2 coats)	0.161		95.634	162.954	0.3658125
Plaster	0.226666667		67.32		

Figure 7. Embodied carbon in external walls

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Internal Walls

Inernal Walls Type 1 (150mm)

Material	Linear Infill (m infil per m) (m)	Depth (X axis) (m)	Density (kg/m³)	Mass (kg/m²)	Embodied Carbon per kg (kgCO₂e/kg)	Embodied kgCO₂e/m	Area (m²)	Ground Floor Linear M	First Floor Linear M	Mass (kg)	Carbon (kgCO2e)	Total Wall Type 1 Carbon	Wall Type 1 Carbon per m²	Total Carbon	Sequester Mass	Co2 Sequestered
							223.47	30.525	47							
12.5mm Plasterboard	1	0.0125	950	11.875	0.39	4.63125				2653.70625	1034.94544	2772.261	12.4056175	3099.04195	6502.48188	-4114.88078
125x50mm Stud at 600 ctrs	0.083	0.125	480	4.98	-1.29	-6.4242				1112.8806	-1435.616					
100mm Acoustic Rockwool	0.917	0.1	25	2.2925	1.371	3.1430175				512.304975	702.370121					
12.5mm Plasterboard	1	0.0125	950	11.875	0.39	4.63125				2653.70625	1034.94544					

Inernal Walls Type 2 (500mm)

Material	Linear Infill (m infil per m) (m)	Depth (X axis) (m)	Density (kg/m³)	Mass (kg/m²)	Embodied Carbon per kg (kgCO₂e/kg)	Embodied kgCO₂e/m	Area (m²)	Ground Floor Linear M	First Floor Linear M	Mass (kg)	Carbon (kgCO2e)	Total Wall Type 2 Carbon	Wall Type 2 Carbon per m²
							64.96	13.2	10				
Pirrouet*: carbon-negative Brick Slips	1	0.02	900	18	0.27733	4.99194				1169.28	324.276422	204.170417	3.1430175
15mm OSB Sheeting	1	0.015	1300	19.5	-1.05	-20.475				1266.72	-1330.056		
200x50mm Stud at 600 ctrs	0.083	0.2	480	7.968	-1.29	-10.27872				517.60128	-667.70565		
100mm Acoustic Rockwool	0.917	0.1	25	2.2925	1.371	3.1430175				146.9208	204.170417		
15mm OSB Sheeting	1	0.015	1300	19.5	-1.05	-20.475				1266.72	-1330.056		
Pirrouet*: carbon-negative Brick Slips	1	0.02	900	18	0.27733	4.99194				1189.28	324.276422		

Finishes	Embodied Carbon per m² (for single coat) (kgCO₂e/kg)	Area (m²)	Carbon (kgCO2e)	Total Finish Carbon	Finish Carbon per m²
		223.47			
Paint (2 coats)	0.161		71.95734	122.61054	0.42573104
Plaster	0.226666667		50.6532		

Figure 8. Embodied carbon in internal walls

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Roof

Roof Type 1 - Clay Tiles

Material	Linear Infill (m infil per m) (m)	Depth (X axis) (m)	Density (kg/m³)	Mass (kg/m²)	Embodied Carbon per kg (kgCO₂e/kg)	Embodied kgCO₂e/m	Area (m²)	Mass (kg)	Carbon (kgCO2e)	Roof Type 1 Carbon	Roof Type 1 per m²	Total Roof Carbon	Total Roof Carbon per m²	Sequester Mass	Co2 Sequestered
							211								
Clay Tiles	1	0.01	2000	20	0.48	9.6		4220	2025.6	4488.6335	21.2731446	4488.6335	21.2731456	7909.968	-9216.37872
25x25 Battens 300cts	0.083	0.025	480	0.996	-1.29	-1.28484		210.156	-271.10124						
50x50 Batten 600 ctrs	0.083	0.05	480	1.992	-1.29	-2.56968		420.312	-542.20248						
Actis Boost R Hybrid (35mm)	0.917	0.035	18.57	0.59600415	4.063	2.421564861		125.756876	510.950166						
15mm OSB Sheeting	1	0.015	1300	19.5	-1.05	-20.475		4114.5	-4320.225						
170mm Actis Hybris between Studs	0.875	0.17	9.13	1.3580875	2.283	3.100513763		286.556463	654.208404						
225x50mm C24 Stud at 400 ctrs	0.125	0.225	480	13.5	-1.29	-17.415		2848.5	-3674.565						
Actis H Control Hybrid (45mm)	0.875	0.045	9.5	0.3740625	4.063	1.519815638		78.9271875	320.681163						
25x50mm Vertical Batten at 400 ctrs	0.125	0.025	480	1.5	-1.29	-1.935		316.5	-408.285						
12.5mm Plasterboard	1	0.0125	950	11.875	0.39	4.63125		2505.625	977.19375						

Figure 9. Embodied carbon in roof

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Elevation

Elevation	Unit Area (m²)			Total Area	Mass (kg/m²)	Embodied kgCO2e/m²	Mass (kg)	Embodied kgCO2e	Total Glazing Carbon	Total Glazing Carbon per m²	Sequester Mass	Co2 Sequestered
North	14.54											
East	43.13		Unit	114.32	20	29.3	2286.4	3349.576	3297.44608	29.3	685.92	-1042.5984
South	21.79		Frame (for Sequester Value)	34.296	20	-1.52	685.92	-52.12992				
West	29.66											
Rooflight	5.2											
Total Unit Area	114.32											
Total Frame Area	34.296											

Figure 10. Embodied carbon in windows

	Total EC A1-3	total mass	transport co kgCO2e	kgCO2e	Pre-Construction Demolition A5.1	Construction Activities A5.2*	WF coeficient	Wastage A5.3	B1* <1000m² therefore negligable	B2* 10*0.23kgCO2e/m of GIA	B3* 25% of B2	B4-B5*	B6-B7 (RICS based)	C1*	C2*	C3	C4
Foundations	11442	197775	0.005	989	3550.75	11520	0.010	1978	0	672.222494	168.06			0.025	2880	4092.45	573	24626
Floors (inc. Finishes)	19776	156293	0.032	5001			0.011	1735				5594.6075					
External walls (inc. Finishes)	5125	24178	0.005	121			0.010	242				499.554					
Internal walls (inc. Finishes)	3099	12471	0.005	62			0.010	125				482.39724					
Windows	3297	2972	0.16	476			0.001	3				3297.44608					
Roofs (inc. Finishes)	4488	15126	0.005	76			0.050	756				2025.6					
steel frame	0	0	0.026	0			0.010	0									
additional materials																	
FF&E	3168											10368					
Services (MEP)	6744											9792					
TOTAL	57139			6725	3551	11520		4838	0	672.222494	168.06	32059.6048	1428.475		2880	4092.45	573	24626

Figure 11. Calculation of life cycle carbon for stages A1-C4

2.2.4 Sequestered carbon

Sequestration is the process by which CO_2e is removed from the atmosphere and stored within bio-based materials such as timber, providing a negative $kgCO_2e$ in the Whole Life Carbon Analysis; however, as to not mask any positive $kgCO_2e$ elements, sequestered carbon is reported separately, and shown in purple.

The timber construction of the proposal, paired with sustainable practices and carbon negative bricks result in 45,020 $kgCO_2e$ of sequestered greenhouse gases, or 156.3 $kg/CO_2e/m^2$.

Over upfront embodied carbon (modules A1-5) the proposal uses 388 $kgCO_2e/m^2$, below the RIBA 2030 target.

For modules A1-C4 the building uses 440 $kgCO_2e/m^2$, below both the RIBA and LETI 2030 target.

3 PHPP Energy Efficiency and Thermal Performance

3.1 U-Values

U-value of building assemblies

178 / Climate: Silsoe / TFA: 260 m² / Heating: 15.5 kWh/(m²a) / Freq. overheating: 35 % / PER: 1.3 kWh/(m²a)

Secondary calculation: Equivalent thermal conductivity of still air spaces -> (on the righ
Wedge-shaped assembly layer -> (on the righ
Unheated / uncooled attic -> (on the righ

Assembly no.	Building assembly description		Interior insulation?
01ud	**Timber frame clay tiles**		

Heat transmission resistance [m²K/W]

| Orientation of building element | **2-Wall** | interior R_si | 0.13 |
| Adjacent to | **1-Outdoor air** | exterior R_se | 0.04 |

Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
clay tiles						
breather membrane						
OSB	0.130					12
140 ACTIS Hybris	0.033					140
200 timber stud@400 ctrs	0.170	airgap	0.026			200
25x50 battens	0.170	ACTIS H-Control Hybris	0.033			50
airgap	0.026					38
plasterboard	0.160					13

Percentage of sec. 1: 40% Percentage of sec. 2: **60.0%** Percentage of sec. 3: Total **45.3** cm

U-value supplement: W/(m²K) **U-value: 0.101** W/(m²K)

Assembly no.			Interior insulation?
02ud	**Ground floor slab**		

Heat transmission resistance [m²K/W]

| Orientation of building element | **3-Floor** | interior R_si | 0.17 |
| Adjacent to | **2-Ground** | exterior R_se | 0.00 |

Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
floor finish						25
screed	0.400					50
polythene 500 gauge						
PIR	0.024					150
polythene damp proof						
reinforced concrete slab	1.400					200
sand blinding	0.250					50
hardcore	2.500					150

Percentage of sec. 1: 100% Percentage of sec. 2: Percentage of sec. 3: Total **62.5** cm

U-value supplement: W/(m²K) **U-value: 0.144** W/(m²K)

Assembly no.			Interior insulation?
03ud	**Roof**		

Heat transmission resistance [m²K/W]

| Orientation of building element | **1-Roof** | interior R_si | 0.10 |
| Adjacent to | **1-Outdoor air** | exterior R_se | 0.04 |

Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
clay tiles	0.800					4
50x50 batten	0.160					50
breather membrane						0
25x50 counter batten	0.160					25
OSB	0.130					12
200x50@400 ctrs timber rafters	0.160	Rockwool Flexi	0.033			200
STEICO therm	0.036					60
plasterboard	0.130					13

Percentage of sec. 1: 10% Percentage of sec. 2: **90.0%** Percentage of sec. 3: Total **36.4** cm

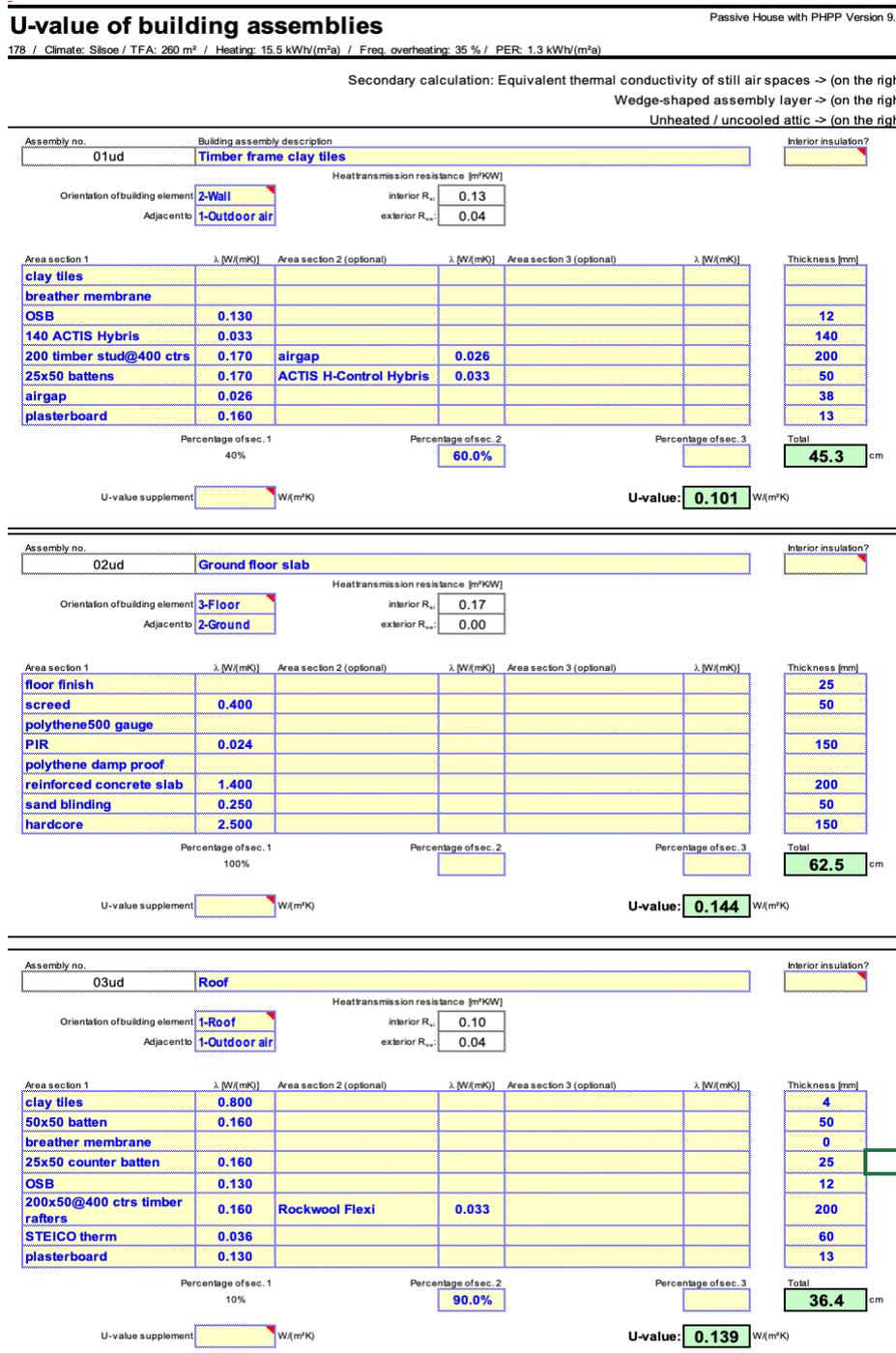U-value supplement: W/(m²K) **U-value: 0.139** W/(m²K)

Figure 12. U-values of constructions calculated in PHPP

3.2 PHPP Energy Efficiency Analysis

The proposed building performance has been assessed through PHPP, used to assess the Passive house performance as per table 3, section 7.1 Step 0: Choosing the modelling approach of CIBSE TM:2022. Evaluating operational energy use at the design stage.
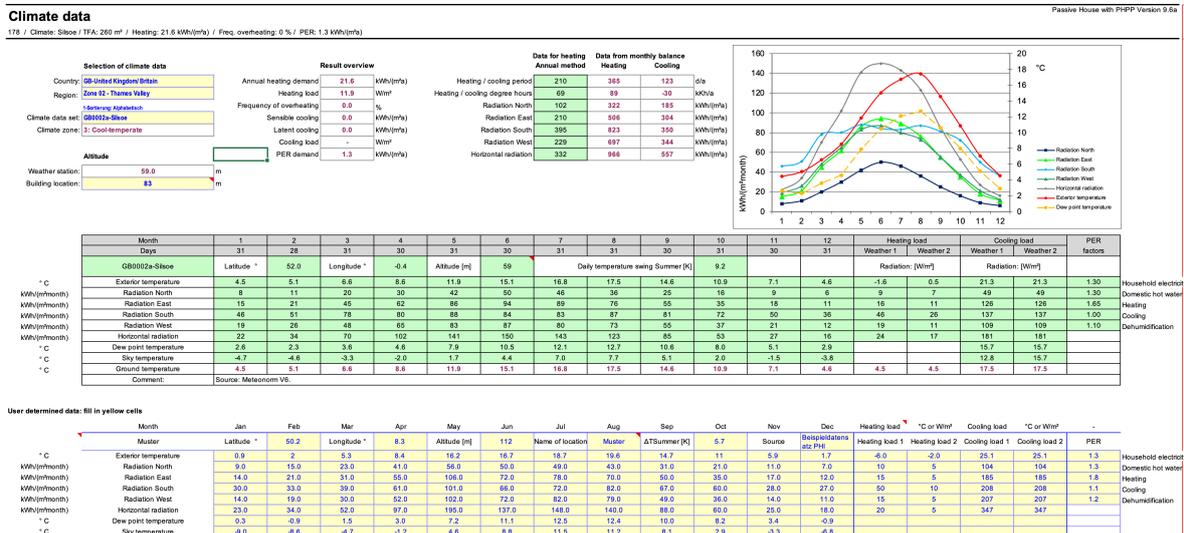
Climate data

Passive House with PHPP Version 9.6a

178 / Climate: Silsoe / TFA: 260 m² / Heating: 21.6 kWh/(m²a) / Freq. overheating: 0 % / PER: 1.3 kWh/(m²a)

Selection of climate data		Result overview				Data for heating Annual method	Data from monthly balance Heating	Cooling	
Country:	GB-United Kingdom/Britain	Annual heating demand	21.6	kWh/(m²a)	Heating / cooling period	210	365	123	d/a
Region:	Zone 02 - Thames Valley	Heating load	11.9	W/m²	Heating / cooling degree hours	69	89	-30	kKh/a
	1-Sortierung: Alphabetisch	Frequency of overheating	0.0	%	Radiation North	102	322	185	kWh/(m²a)
Climate data set:	GB0002a-Silsoe	Sensible cooling	0.0	kWh/(m²a)	Radiation East	210	506	304	kWh/(m²a)
Climate zone:	3: Cool-temperate	Latent cooling	0.0	kWh/(m²a)	Radiation South	395	823	350	kWh/(m²a)
		Cooling load	-	W/m²	Radiation West	229	697	344	kWh/(m²a)
Altitude		PER demand	1.3	kWh/(m²a)	Horizontal radiation	332	966	557	kWh/(m²a)
Weather station:	59.0	m							
Building location:	83	m							

Figure 13. Climate data according to PHPP climate zones

Areas determination

Passive House with PHPP Version 9.6a

178 / Climate: Silsoe / TFA: 211 m² / Heating: 20.4 kWh/(m²a) / Freq. overheating: 40 % / PER: 1.3 kWh/(m²a)
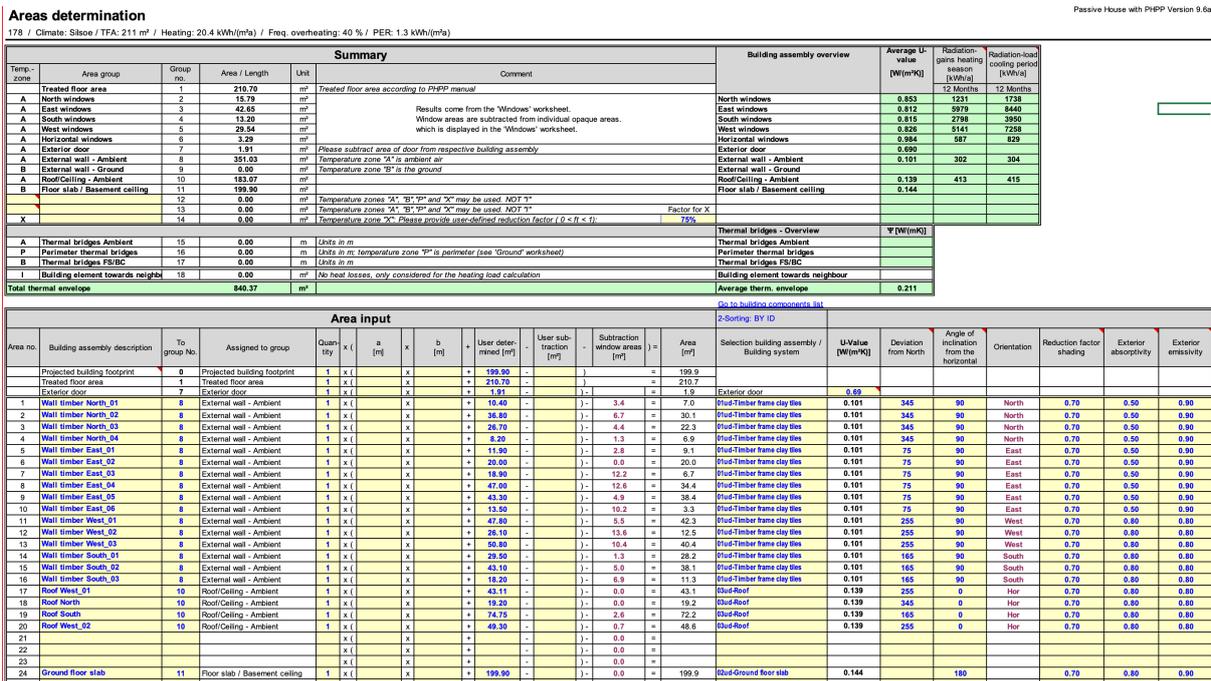
Figure 14. Areas of the proposed building specifying construction and orientation

Specific energy for heating (monthly method)

178 / Climate: Silsoe / TFA: 211 m² / Heating: 20.4 kWh/(m²a) / Freq. overheating: 40 % / PER: 1.3 kWh/(m²a)

		Interior temperature:	20	°C
		Building type:		
		Treated floor area A_{TFA}:	211	m²

|	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating degree hours - External	11.8	10.3	10.3	8.5	6.3	3.8	2.7	2.2	4.2	7.0	9.5	11.7	88	kKh
Heating degree hours - Ground	6.9	6.7	7.5	6.9	6.4	5.4	4.8	4.3	4.0	4.5	5.0	6.1	68	kKh
Losses - Exterior	2064	1796	1794	1488	1107	671	468	377	729	1231	1667	2047	15438	kWh
Losses - Ground	197	192	215	198	185	155	137	123	116	130	145	175	1967	kWh
Sum spec. losses	10.7	9.4	9.5	8.0	6.1	3.9	2.9	2.4	4.0	6.5	8.6	10.5	82.6	kWh/m²
Solar gains - North	34	47	84	126	173	203	185	148	103	66	37	24	1231	kWh
Solar gains - East	121	183	422	615	880	983	925	765	532	317	150	87	5979	kWh
Solar gains - South	149	166	258	268	300	290	286	295	270	237	163	117	2798	kWh
Solar gains - West	187	241	425	541	670	687	639	602	475	342	206	126	5141	kWh
Solar gains - Horiz.	13	21	43	62	86	91	87	75	52	32	16	10	587	kWh
Solar gains - Opaque	37	50	96	130	172	181	173	153	112	76	43	27	1249	kWh
Internal heat gains	643	581	643	622	643	622	643	643	622	643	622	643	7568	kWh
Sum spec. gains solar + internal	5.6	6.1	9.3	11.2	13.9	14.5	13.9	12.7	10.3	8.1	5.9	4.9	116.5	kWh/m²
Utilisation factor	98%	95%	84%	67%	44%	27%	21%	19%	39%	72%	95%	99%	53%	
Annual heating demand	1101	756	355	106	13	1	0	0	5	121	642	1201	4301	kWh
Spec. heating demand	5.2	3.6	1.7	0.5	0.1	0.0	0.0	0.0	0.0	0.6	3.0	5.7	20.4	kWh/m²
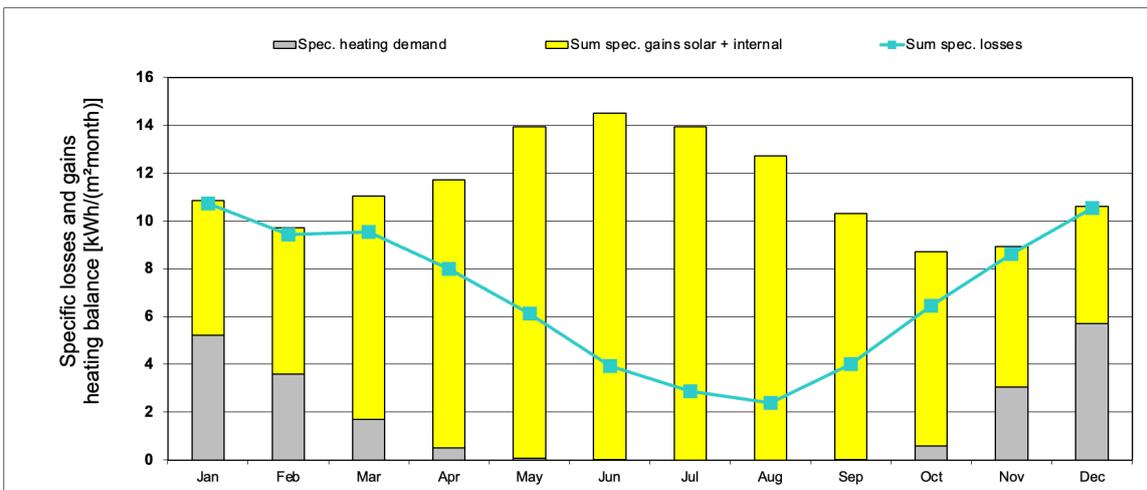
Figure 15. Heat losses and solar gains

Windows

178 / Climate: Silsoe / TFA: 211 m² / Heating: 20.4 kWh/(m²a) / Freq. overheating: 40 % / PER: 1.3 kWh/(m²a)

Window area orientation	Global radiation (main orientations)	Shading	Dirt	Non-vertical radiation incidence	Glazing fraction	g-Value	Solar irradiation reduction factor	Window area	Window U-Value	Glazing area	Average global radiation		Transmission losses heating period	Heating gains solar radiation heating period
Standard values →	kWh/(m²a)	0.75	0.95	0.85				m²	W/(m²K)	m²	kWh/(m²a)		kWh/a	kWh/a
North	102	0.75	0.95	0.85	0.67	0.62	0.40	15.79	0.85	10.55	108	North	930	426
East	210	0.75	0.95	0.85	0.70	0.62	0.42	42.65	0.81	29.77	175	East	2391	1953
South	395	0.75	0.95	0.85	0.68	0.62	0.41	13.20	0.82	8.98	386	South	743	1302
West	229	0.75	0.95	0.85	0.69	0.62	0.42	29.54	0.83	20.35	268	West	1684	2049
Horizontal	332	0.75	0.95	0.85	0.69	0.44	0.42	3.29	0.98	2.28	332	Horizontal	224	201
Total or average value for all windows.						0.61	0.42	104.47	0.83	71.93			5972	5932

Figure 8=16. Solar radiation through the windows

Transmission losses heating period	Heating gains solar radiation heating period
kWh/a	kWh/a
930	426
2391	1953
743	1302
1684	2049
224	201
5972	5932

Design temperature [°C] (from location *)

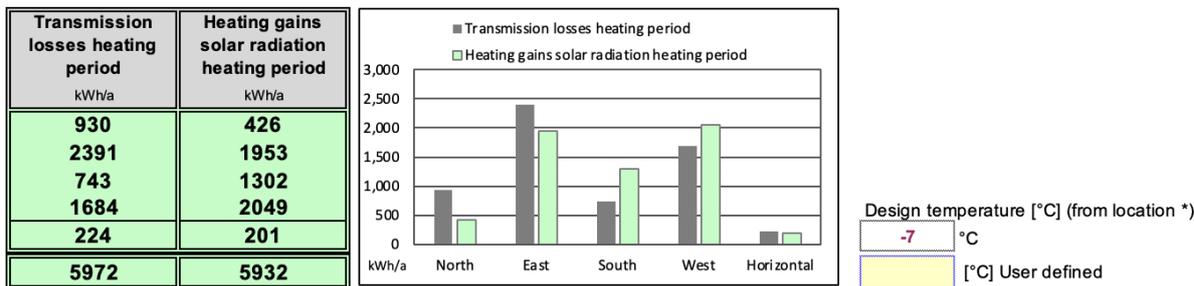| -7	°C
	[°C] User defined

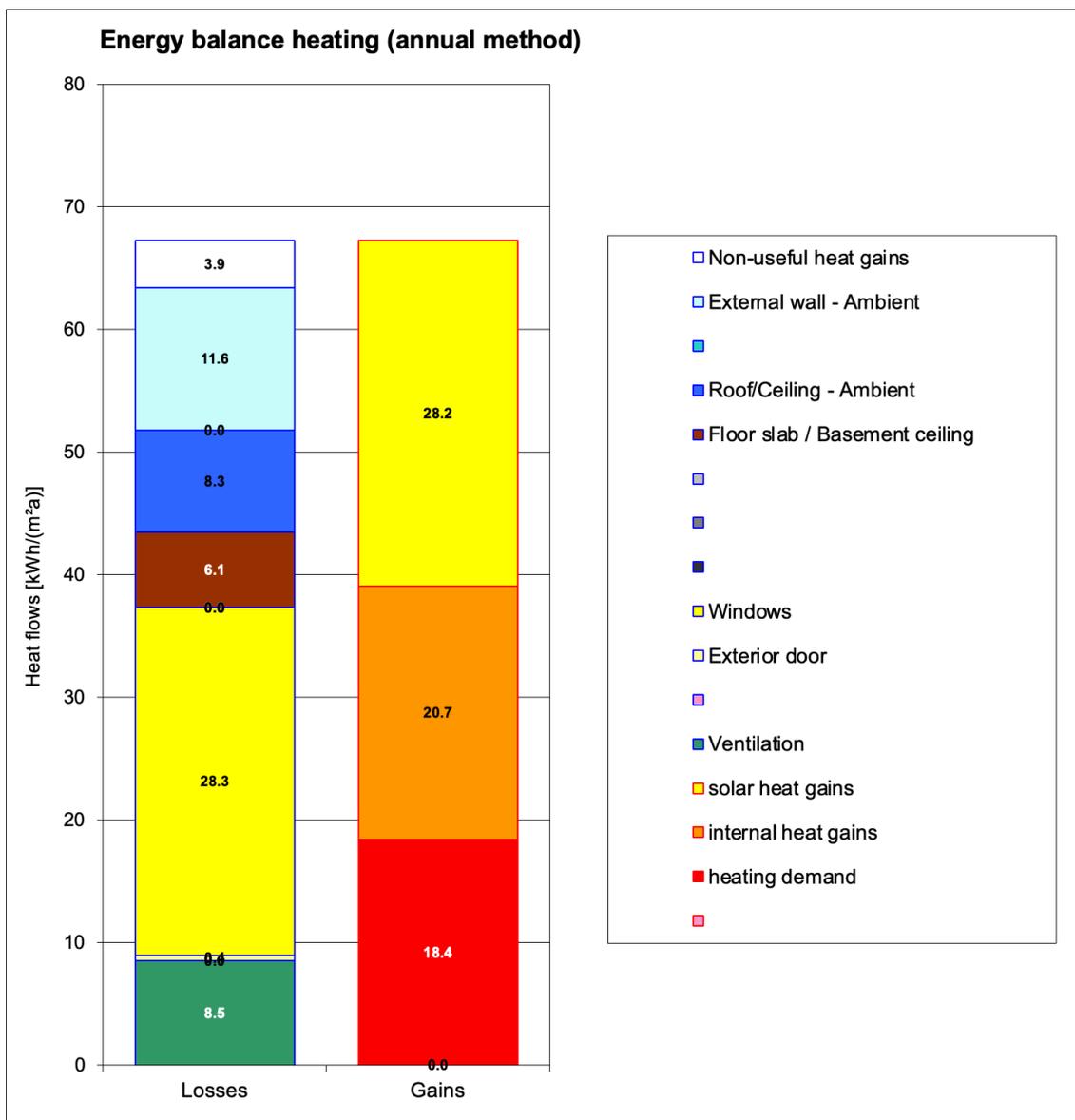*Figure 17. Balance of heat losses and solar gains through the windows*

Figure 18. Energy balance for the new building

The PHPP calculations show the improved form factor, air tightness, orientation and materiality of the dwelling reduce the operational energy to 19 kWh/m², far below the national new build average of 82.23kWh/m², and the existing dwelling average of 223kWh/m² (Home Builders Federation, 2023). The Passivhaus Trust set the highest Passivhaus standard at 15kWh/m², just 4kWh/m² below our proposal.

A new building with net zero operational carbon does not burn fossil fuels and is 100% powered by renewable energy and achieves a level of energy performance in-use in line with our national climate change targets. This means that an operational carbon balance is met, see Figure 19.
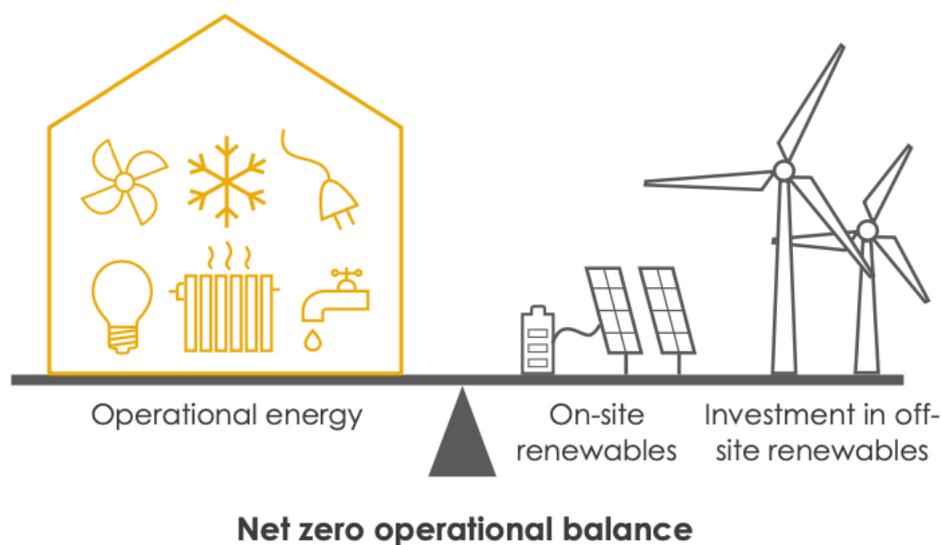

Figure 19. Net zero operational balance – at the building scale

The proposed scheme uses 19kWh/m^2/yr for space heating over the 288m^2 GIA, totalling an expected energy usage per annum of 5472kWh/yr. Further to this, The Passive House Institute state the combined energy usage for all domestic applications, heating and other, must not exceed 30 kWh/m^2/yr (8640kWh/yr) as calculated via the PER method.

To achieve the PHI and local energy targets of 30kWh/m^2/yr the proposal will utilise the elements highlighted in the PHPP analysis along with an MVHR and ASHP unit. This total energy cost of the dwelling can be generated onsite with the use of photovoltaic panels as outlined below.

30kWh/m^2/yr over 288m^2 GIA results in a total dwelling energy requirement of 8640kWh per year. Where one photovoltaic panel generates on average 1.44 kWh output per day, equating to circa 525.6 kWh per year.

These calculations show to meet the 8640kWh yearly demand a total of 17 PV panels will be required. More specific calculations by energy specialists could be used in the technical design stage to ensure the PV array is suitable.

The proposal currently exceeds the 17PV requirement with a proposed 28 PV panels, generating an estimated 14,716kWh/yr.

4 Conclusion

Whole life carbon is formed of two key components Operational Carbon + Embodied Carbon

Operational Carbon: A new building with net zero operational carbon does not burn fossil fuels, is 100% powered by renewable energy, and achieves a level of energy performance in-use in line with our national climate change targets.

Embodied Carbon: Best Practice targets for embodied carbon are met, and the building is made from re-used materials and can be disassembled at its end of life in accordance with circular economy principles.

Due to the operational energy demands of the dwelling being met by the PV's, while providing significant excess, the operational carbon of the dwelling is considered to be Net Zero.

The Embodied carbon of the dwelling for 60 years, including repairs, the eventual demolition, disposal and recycling of the dwelling come to 304 $kgCO_2e/m^2$, less than 1/3 of the national average, and far above the RIBA and LETI 2030 target. The upfront cost of the dwelling (A1-A5) also comfortably exceeds the RIBA and LETI 2030 target of 234 $kgCO_2e/m^2$. Therefore, we view this building as be incredibly sustainable for both for the present day and future use.

The RIBA 2030 Climate Challenge built performance is equivalent of a B rating (note that this assumes practical completion in 2030, so designed earlier).

Signposting
This document is designed to be read with other LETI documents including the:
- LETI Embodied Carbon Primer
- Whole Life Carbon and Embodied Carbon One Pagers
- Net Zero Carbon Definitions
- Reporting templates on the LETI website
- FAQs available on the LETI website

Figure 20. Achieved lifetime carbon analysis