# SUSTAINABLE RETROFIT PLAN PRE-1919 MID OF TERRACE HOUSE

# <u>Abstract</u>

This paper explores, the challenge of reducing OC<sup>1</sup> emission in 95% from those of 1990 in the Wales housing old stock through different retrofit options for apre-1919 mid of terrace house, developing the most feasible and cost-effective of them. Furthermore, an analysis of a significant feature of the refurbishment is carried out, to understand the relation between the savings in OC when upgrading a building and the EC<sup>2</sup> emissions involved in that process.

# Table of contents

- 1. Introduction
- 2. Methodology
- 3. Domestic Retrofit Operational Carbon
  - 3.1. Base case and approach.
  - 3.2. Contemplated Scenarios. Feasibility and costs.
  - 3.3. Retrofit "8". Detailed Strategy:
    - 3.3.1. Fabric Insulation Upgrade
    - 3.3.2. Airtightness Upgrade
    - 3.3.3. Renewables technologies
- 4. Wall upgrade -Embodied Carbon
  - 4.1. Option 1. Non-Breathable Wall Upgrade
  - 4.2. Option 2. Breathable Wall Upgrade
  - 4.3. Comparison
- 5. Conclusions : Operational vs Embodied Carbon
- 6. References
- 7. Appendix A. Floor Plans
- 8. Appendix B. Retrofit "8" SAP Model
- 9. Appendix C.- PV-Panels Details from Manufacture.
- 10. Appendix D. The Carbon Calculator. Reports

<sup>&</sup>lt;sup>1</sup> Operational Carbon

<sup>&</sup>lt;sup>2</sup> Embodied Carbon

#### 1. Introduction

Currently, the levels of  $CO^2$  in the atmosphere are 400 parts per million over the safe limit of 350 (Stevenson, 2020), and the construction industry is responsible of 39% of CE<sup>1</sup> in the world (Sassi, 2006). That is why regulations have set up very ambitious targets for cutting down the building carbon footprint<sup>2</sup>. Particularly, UK government aims to reduce at least 80% the emissions from 1990 levels, with a special emphasis in the domestic sector as it is responsible for 33% of the emissions. However Wales has committed to reach a 95% reduction, because although its domestic sector emissions are only a 21% of the total, this higher goal pursue to balance the industrial sector who is responsible for 55% of the CE in Wales against the 39% of the UK industry sector (Green, et al., 2019).

In addition to this challenge, Wales must also face that the 35% of the stock housing was built before 1919, owning one of the oldest housing stocks in Europe (Green, et al., 2019). Then, it is highly likely that additional upgrades are required against other stocks, which are to be essential as it is predicted that 90% of the actual stock will keep in use by 2050 (Green, et al., 2019).

On this ground, this paper aims to explore effective and feasible strategies for retrofitting a pre-1919 mid of terrace house (Figure 1) in order to reach the set target in Wales. Furthermore, it seeks a wider understanding of not only the  $0C^3$  emissions of the building, but also its relationship with the  $EC^4$  of the elements involved.



Figure 1. Front House View

designs

#### 2. Methodology

For that purpose, the research is diveded in two main sections: the exploration and development of a retrofit plan and the analysis of a significant element of the refurbishemnt. Therefore, an utter understanding is achieved of thre upgrade impact onto the total building carbon footprint. Inasmuch as , if it is true that OC has been higly reduce in the last years (Figure 2), the EC have been kept in the same levels. However, to reduced the carbon footprint further, more attention to  $EC^5$  emmisions is essential and its understanding. (Banteli, 2020).

First, the current stage of the house is analyze and its OC footprint is stablished as well as the principales to adress the problematic. Then, different options are modelled in the SAP tool (CRIBE, 2014) and analysed in terms of their feasibility and costs. To ultimately develop and detail the most efficient strategy to

 Kg CO<sub>2</sub>/m²/year

 0
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 100
 150

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 Best practice
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Embodied and operational carbon for low carbon

Figure 2. Embodied and OC for Low Carbon Designs. (Banteli, 2020)

feasibility and costs. To ultimately develop and detail the most efficent strategy to achieve the 95% target.

On the second part, the wall upgrade will be analysed in detail since it is the meassure wich will required more quantity of materials as shown later, which likely be translate in higher EC emissions. Whilst also, it is one of the most effcient measures to cut down the OC. With this purpose, two alternative systems are compared in terms of its EC, cradle to grave boundary<sup>6</sup>. Ultimately, the EC of the most suitable one is compared against the savings in OC emmisions due to the wall upgrade during its lifecycle.

<sup>5</sup> EC = Embodied Carbon

<sup>&</sup>lt;sup>1</sup> CE = Carbon Emissions

<sup>&</sup>lt;sup>2</sup> Carbon Footprint = "A 'carbon footprint' is the total amount of CO2and other greenhouse gases, emitted over the full life cycle of a process or product.". (Stevenson, 2020)

<sup>&</sup>lt;sup>3</sup> OC =Operational Carbon = Amount of the CO2 emissions related to the building in use during its full lifecycle. Such as those produced by heating or lighting. (Stevenson, 2020)

<sup>&</sup>lt;sup>4</sup> Embodied Carbon = CE linked to the harvest, transport, manufacturing, installation, disposal and/or recycled of any product or process involved in the construction of the building. (Stevenson, 2020)

<sup>&</sup>lt;sup>6</sup> Cradle to Grave Boundary = Embodied carbon from a product or elements since it is harvested as raw material to the end of its lifecycle.

## 3. Domestic Retrofit – Operational Carbon

#### 3.1. Base Case and approach.

The pre-1919 mid of terrace house is in King Street, Pentre (Wales), has north–south orientation and a refurbishment has already been carried out previously there, which resulted in a 56% reduction of its OC emissions. The main changes were as follows (Lannon, 2020):

- 50 mm of insulation between the rafters 6% <sup>1</sup>
- New Double-glazed Windows, PVC frames and doors. U-value =3 2% <sup>1</sup>
- Chimney removal- Air tightness improvement together with Windows and doors improvement Airtightness = 10 m<sup>3</sup>/m<sup>2</sup>h (Normal Practice) 3%<sup>1</sup>
- Gas Combi Boiler (90% efficiency) 43% <sup>1</sup>
- 100% Low energy Lights 2%<sup>1</sup>

Then, the strategy was based on an individual upgrade, the boiler, and the avoidance of high-risk interventions or the use of highly skilled workers. The result of that is the need of a "Fabric First approach"<sup>2</sup> (Lannon & Green, 2020) in the current refurbishment as it is the only route towards reducing heating demand thus emissions can be diminish further.

Otherwise limited improvement can be achieved in regards with fuel type or heating system as it is evidenced in the option 4 from the modelled scenarios in the following section.

Nevertheless, the previous retrofit is still an advantage from a cost point of view too (Figure 3) as to reach the final goal of 95% reduction at once might end up on average around £800/ m<sup>2</sup>, while the savings will not rises that much, so reasonable payback periods are difficult to achieve (Jones, et al., 2013). Then, retrofitting in two phases to reach the 95% reduction is more beneficial for the owners.



Figure 3. Summary of Costs versus savings for different retrofit strategies.

#### 3.2. Contemplated Scenarios. Feasibility and costs.

Following the "First Fabric" approach, different scenarios (Table 1) have been conceived and complemented using renewable energies as suggested in most of the literature such as McCaig, et al. (2018) and study cases. For example, 15 Passmore street (Westminster City Council, 2013) or in high number of cases on "Homes of today for tomorrow" (Green, et al., 2019).

In order to assess the options, all are modelled in the SAP tool (CRIBE, 2014) and 4 main characteristics are studied individually and as a part of each scenario: intensity, contribution to the carbon reduction, feasibility and cost (Tables 2-5).

ANALYSED SCENARIDS											
OPTION		FAE	BRIC			INFILTRATION	M\/UD	RENEW	IABLES	Number Astions	
	WALLS	FLOOR	RODF	WINDOWS	LEATING 9191EM	RATE	MALIK	SOLAR THERMAL	PHOTOVOLTAIC	Number Actions	JAL MUDEL FINK
1	Х	Х				Х	Х	Х	Х	6	http://bit.ly/2TPybxA
2	Х	Х	Х			Х	Х	Х	Х	7	https://bit.ly/3drMHU6
3	Х	Х	Х			Х	Х		Х	6	http://bit.ly/33lwevW
4	Х	Х	Х	х	Х	Х	Х		Х	8	https://bit.ly/33zhjhK#
5	Х	Х	Х						X	5	https://bit.ly/2Wv8LXD
6	Х	Х	Х			Х	Х		X	7	https://bit.ly/3bjh25r
7	Х	Х	Х					Х		5	https://bit.ly/2xhJlg5
8	Х	Х	х			Х		х	х	6	https://bit.ly/3aecSLS
9	Х	Х	Х			Х			Х	5	https://bit.ly/2Qz0Q66

Table 1

<sup>2</sup> First Fabric Approach = It consists in the massive improvement of the building fabric to diminish the energy demand for heating as much as it is possible.

<sup>&</sup>lt;sup>1</sup> X% = percentage of emission reduction due to each upgrade

Overall, examining the results carefully the most cost-effective options are those with a whole fabric upgrade but not extremely low values as it is observed that under 0.15-0.20 W/ m<sup>2</sup>K, there is little or no improvement and technically it is to be difficult of achieve. Furthermore, it can be appreciated the high contributions of photovoltaic panels, 10-13% (Table 3) and how their prices have decrease along the years (Table 5) making them cost effective.

However, making the "First Fabric" approach feasible can be a little intricate (Table 4) due to site dimension constrictions, the high disturbance for occupants or the need of high skilled workers (McCaig, et al., 2018). That is why is crucial to complement this measures with others which do not add further risks. Then, options that contemplates MVHR, PV arrays over 2 kWP or emerging technoloigies are rule out (Table 4). Finally, option 8 stands out as the most suitable option because is intensively based on a "Fabric First" approach, but within the constrains limits, and supported by reliable renewable technology. The specific features of the retrofit are developed on the next point.

NPTINN		FΔF	RIC	INTENSITY	JF THE MEASURES	ΙΝΕΙΙ ΤΡΑΤΙΩΝ		RENEW	ARIES
	WALLS	FLOOR	ROOF	WINDOWS	HEATING SYSTEM	RATE	MVHR	SOLAR THERMAL	PHOTOVOLTAIC
Base Case	2.1	2	0.6	3	Gas	normal practice	ND	ND	ND
1	0.3	0.25				3m3/m2h	YES	6sqm	2Kwp
2	0.3	0.3	0.35			3m3/m2h	YES	4sqm 2Kwp	
3	0.25	0.14	0.25			3m3/m2h	YES		2.5KWP
4	0.1	0.1	0.1	1.2	HEAT PUMP	3m3/m2h	YES		1kwp
5	0.6	0.2	0.2					2.5 kwp + 6m	2 PV-T Panels
6	1	0.45	0.2			3m3/m2h	YES	2.5 kwp + 6m	2 PV-T Panels
7	0.25	0.15	0.25					2.5 kwp + 3m2 PV-T Panels	
8	0.2	0.15	0.2			5m3/m2h		4sqm	2Kwp
9	0.2	0.15	0.2			5m3/m2h			Зkwp



Easy to do

Moderate

Difficult to do

Table 2

	EFFICIENCY OF THE MEASURES												
OPTION		FAE	BRIC		HEATING SVSTEM	INFILTRATION	MV/HP	RENEW	ABLES				
	WALLS	FLOOR	ROOF	WINDOWS		RATE	PITIN	SOLAR THERMAL	PHOTOVOLTAIC	CO2 kg yearly	1-5%		
1	8%	10%				2%	3%	6%	10%	336			
2	10%	10%	1%			<b>2</b> %	<b>Z</b> %	4%	10%	400	6-9%		
3	10%	10%	<b>2</b> %			1%	3%		13%	352			
4	10%	10%	<b>2</b> %	4%	5%	1%	<b>2</b> %		<b>5</b> %	376	>10%		
5	8%	9%	3%					6%	13%	400			
6	6%	7%	2%			2%	3%	6%	13%	376			
7	10%	10%	<b>2</b> %					4%	13%	400			
8	10%	10%	<b>2</b> %			1%		5%	11%	400			
9	10%	10%	2%			1%			<b>16</b> %	376			

Table 3

FEASIBILITY *											
OPTION		FAB	iric			INFILTRATION	MVUD	RENEW	IABLES		
	WALLS	FLOOR	RODF	WINDOWS		RATE	MALIK	SOLAR THERMAL	PHOTOVOLTAIC	Easy to	
1								🗸 20sqm Avi	ailable. Limited		
1							✓ LIMITATIONS	spi	308	Moder	
2	High Disturbance. House		✓				in Floor to	✓	✓		
3			✓				ceiling height	ceiling height		Difficu	
4			~	4	✓ under staircase	✓ very high skilled work	n=2.am		✓		
5	. unoccupied	is required.	✓			torced required		✓ Emerging technologies			
6	Limitations in cei considered for Reductions in vo W	ling heights to be floor insulations. lume because of 1*1	~				✓ Limitations in Floor to ceiling height h=2.5m				
7			1								
8			1			y yony high		1	✓		
9			✓			skilled work forced required			✓ 20sqm Available. Limited space		

Table 4

		APP	PROXIMATE CAPITAL	. COST £ - (based	l on Lee Wakeman	cost consultants	)* *5					
OPTION		FAE	3RIC			RENEWABLES		BLES*7				
	WALLS	FLOOR	ROOF*2	WINDOWS*3	TEATING ST STEM		MANIN	SOLAR THERMAL	PHOTOVOLTAIC			
Base Case			830	4500	5100	415				10845		
2	1958	2076	830			415	1760	3000	5000	15039		
4	1958		830		11600	415	1760		5000	21563		
7	1958	2076	830					8000		12864		
8	1958	2076	830			415		3000	5000	13279		
	APPROXIMATE CAPITAL COST £ - (Westminster City Council)* *6											
OPTION		FAE	3RIC				M//UD*/0	RENEWABLES*7				
	WALLS	FLOOR*10	ROOF*2	WINDOWS	LEALING 21 21EM	IFILIIKAIIUN KAIE	MINULL	SOLAR THERMAL	PHOTOVOLTAIC	IUTAL CUSTS		
Base Case		875	352	3450	2550	250				7477		
2	5600	917	352			250	1760	5000	13000	26879		
4	8500		352		11600	250	1760		13000	35462		
7	7050	917	352					18000		26319		
8	7050	917	352			250		5000	13000	26569		

Table 5

#### 3.3. Retrofit "8". – Strategy:

This retrofit (See table 6) diminishes the OC up to the 95% required as shown in the SAP model (Appendix B), which means  $5 \text{kg } \text{CO}_2/\text{m}^2$  emissions per year, and considering the total area of the house is 80 m<sup>2</sup>, then the total OC is to be 400 kg CO<sub>2</sub> a year against the current 3256 Kg CO<sub>2</sub> or the 7400 Kg CO<sub>2</sub> equivalent to the levels of 1990 (CRIBE, 2014). In order to materialized that, the different elements of the refurbishment are further detailed below.

				RETRO	FIT "8"							
	FAB	RIC					RENEW	ABLES				
WALLS	FLOOR	ROOF	WINDOWS	Heating system	RATE	MVHR	Solar Thermal	PHOTOVOLTAIC	Number Actions			
X	Х	Х			Х		X	Х	6			
				INTENSITY								
	FAB	RIC			INFILTRATION		RENEW	ABLES				
WALLS	FLOOR	ROOF WINDOWS		HEATING 21.21EM	RATE	MVHK	SOLAR THERMAL	PHOTOVOLTAIC				
0.2	0.15	0.2			5m3/m2h		4sqm	2Kwp				
				EFFIC	IENCY							
FABRIC				HEATING GVGTEM	INFILTRATION	W//HD	RENEWABLES					
WALLS	FLOOR	ROOF	WINDOWS		RATE	וייייווי	SOLAR THERMAL	PHOTOVOLTAIC	CO2 kg yearly			
<b>10</b> %	<b>10</b> %	<b>2</b> %			1%		<b>5</b> %	11%	400			
	FEASIBILITY *											
	FAB	RIC		HEATING OVOTEM	NG SYSTEM INFILTRATION MVHR		RENEW	ABLES				
WALLS	FLOOR	ROOF	WINDOWS		RATE	MALIN	SOLAR THERMAL	PHOTOVOLTAIC				
High Disturbance. House unoccupied is required. Limitations in ceiling heights to be considered for floor insulations. Reductions in volume because of WI*1			✓ very high skilled work forced required		*	~						
		APPROXIMATE C	CAPITAL COST £ -	(based on Lee Wa	keman cost cons	ultants) * *5						
	FABRIC				IEII TRATION BATE*	WVHR	RENEWA	BLES*7				
WALLS	FLOOR	RODF*2	WINDOWS*3			19141 111	SOLAR THERMAL	PHOTOVOLTAIC				
1958	2076	830			415		3000	5000	13279			

Table 6

#### 3.1.1. Fabric Insulation:

It is essential that all insulation is added at the same time to make sure joints between the different elements executed properly are and in coordination with the introduction of permeability measures, commented afterwards. Furthermore, overheating must be considered when u-values are this lo. However according to SAP (CRIBE, 2014), in this case, it can be overcome by "opening the windows half time" (Appendix B) rather than installing shading elements with an over cost associated.

In regard to the walls, because of the historic value and to keep consistency along the street, IWI is added at the Front and back walls, but also because it tends to be cheaper than EWI<sup>1</sup> (Westminster City Council, 2013).





The same report, advices also a breathable solution for the walls upgrade as would reduce the risk of damp issues, particularly in historic buildings. Then, a timber frame cavity wall upgrade with rockwool insulation (Figures 5) is considered. However, another option (Figures 4) is contemplated because of space constrains, phenolic insulation with a vapour barrier as the overall thickness will be reduce from 227'5 mm<sup>2</sup> (Rockwool, 2017) to130'5 mm (Kingspan, 2020). So, while the breathable option will reduce the floor area of each storey by 2.3 m<sup>2</sup>, the phenolic insulation would only take 1.3 m<sup>2</sup>.

	Change thickness [mm]	Manufacturer	Name	Thickness [m], number	Lambda [W/(mK)]	Q	R [m²K/W]
		Rse					0.0400
		Generic Build Stone Wall	Thickness = 0.3 m / Lambda =2.3 (Kingspan 2020).	- R= 1/U = 0.13		D	0.1325
	- 230		automatic disregarding acc. BRE 4.4.3)				
0-value	-	Online	Low E Breather Membrane R=0.77m <sup>2</sup> K/W	0.0500	0.065	E	0.7700
0.00		BS EN 12524	Plywood [500 kg/m <sup>3</sup> ]	0.0095	0.130	D	0.0731
0.20	<b>İ</b>	Inhomogeneous material layer	consisting of:	0.1400	ø 0.049		2.8426
[W/m <sup>2</sup> K]	T	ROCKWOOL Ltd Online	Flexi 140mm - 200mm Level 0: dU'' = 0.00 W/(m²K)	85.00 %	0.035	E	-
	(0	BS EN 12524	Softwood Timber [500 kg/m <sup>3</sup> ]	15.00 %	0.130	D	-
	0 - 80	Inhomogeneous material	consisting of:	0.0250	ø 0.040	_	0.6217
	Insulation thickness	layer	•				
	140 mm	ROCKWOOL Culling	Low E Vapour Control Layor R=0.70m2K/M	01.07.0/	0.022	-8-	
	140 1111	BS EN 12524	Softwood Timber [500 kg/m³]	08.33 %	0.130	P	- 0.0658
		Breathable plasterboard 8	& Finished (left out of preliminary calculations. Very lim	ited contribution f	or U-value.	- 6	0.0052
Figure 5. Wall Built-	up. Rockwool Modified.	BreRsi					0.1300

Furthermore, floor insulation (Figure 6) is to be added over concreate slab, for this the floor finish and skirts must be removed, as well as any inner plaster finished in walls for the earlier commented upgrade. Afterwards, 100 mm of K103 floorboard insulation (See figure 6) will be place after tackling any moisture issues (McCaig, et al., 2018) and must be consider the possibility of having to change doors because of new floor height.

Besides, 50 mm of insulation will be added under the roof rafters (Figure 7), in addition to the exiting 50 mm, to fully achieve the U-values required. Being this the easiest measure, only must be consider the joints with the walls. (Westminster City Council, 2013).

<sup>&</sup>lt;sup>1</sup> EWI = External Wall Insulation

<sup>&</sup>lt;sup>2</sup> Note, the breathable option is not standard Rockwool, neither the stone wall so values have been modified according to BSN ISO 6946 (BSI Standards Institution, 2017).

Calculations		U-volue	Calculations		U-value
Construction type	Floors Walls Pitched Flo	tt Roof 0.20	Construction type	Floors Walls Pitched Flat Roof	0.15
Roof Sub Type ?	Insulation between and under rafters (p.,	<ul> <li>✓ 0.18</li> <li>● 0.28</li> </ul>	Floor Type	Ground floor	0.09 0.25
Ventilation ?	Ventilated	Click here to view construction build-up	Floor Sub-Type	Solid concrete - Insulation below screed	
Presence of sarking board ?	No sarking board	Construction build-up includes: 3mm skim costed Kingspan Kooltherm K118 involtend Biord	PA Ratio ?	0.7 🗸	Click here to view construction build-up V Construction build-up includes:
Rafter depth	175mm	Kingspan Kooltherm K2 Pitched Roof Board partially filling space between	Insulation Thickness	) - 90mm 100mm 110mm + r	óömm screed separation layer Kingspan Kooltherm K103 Floor Board
Rafter centres ?	400mm	Ventilated airspace (minimum 50mm) obve: insulation Sarking felt			150mm concrete slab damp proof membrane hardcore.
Insulated Plasterboard (mm) ?	.575	Tile/skate batten Tile/Slates See website for more details ₽	Tick here if you would like to construction build-up. ?	o receive the BIM Object for this	See website for more details B
Insulation Thickness 7	r - 100wm 110mm 120wm	+ , 5 → Kingspon Koottherm K7 Pitched Roof Board @	For the purposes of these calculations, the	$\label{eq:Emailmethis} \begin{tabular}{c} \mbox{Emailmethis} & \mbox{H} \end{tabular} \end{tabular}$ is soft has been assumed to be sort or growel.	Kingspon Kooltherm K103 Floorboard
Figure 7. Roof Buil	torned between the insulation and the sorting feit to avail t-up. (Kingspan , 2020)	13	Figure 6 . Floor Built-u	p. (Kingspan , 2020)	

## 3.1.2. Airtightness:

At the same time, the required measures for the reduction of air permeability to  $5 \text{ m}^3/\text{m}^2$  must be set in place to create a consistent and continues fabric. However, this is a very difficult measure to quantify beforehand and only with a blower-door test<sup>1</sup> can be checked after the implementation of the retrofit.

Nevertheless, there is extended literature and study cases which shows the successful measures to achieve the 5  $m^3/m^2h$  infiltration rate. Sturgis Carbon Profiling LLP (2013) explains detailed measures to diminished permeability and are meant to be applied in this case:

- Closing existing holes in building walls with insulant and draught stripping at all the apertures
- Closing holes around pipes penetrating the envelope and any holes in the roof or eaves area
- Draught striping loft hatches

Furthermore, a vapour permeable membrane can be added to walls and roof and a "Lime lite" renovating plaster might be added as it limits the air permeability at the same time is a breathable material, reducing the moisture risk. This solutions have been already successfully implemented in "Solcer Retrofit King Street (Social housing)" (Lannon & Green, 2020) achieving up to 0.9 3/m<sup>2</sup>.hr @ 50 Pa.

## 3.1.3. Renewable Energies:

Finally . the "Fabric focus" measures are complemented with the installation of renewable systems on the 16 sqm of suitable<sup>2</sup> roof area will be occupied with 4 m<sup>2</sup> of thermal solar panels connected to the Combi boiler and 10 m<sup>2</sup> of PVarray 2 KWp made up of 5 "UKSOL 380-400W MONO HALF CELL" panels 400Wp (Appendix C) of 1990x992mm. As shown in the table 6, this will add up 16% CO<sup>2</sup> reductions to the 23% savings by the fabric improvements, achieving the 95% as show in Appendix C.

## 4. Wall Upgrade – Embodied Carbon:

Regarding the EC of the elements that are involved in the refurbishment, and as explained earlier, the walls upgrade is analysed as the most representative feature of the retrofit. For that purpose, the two systems, already introduced in section 3.1.1 are analysed. Prior to that, assumptions for both scenarios are taken in order to achieve efficient and realistic results at the same time calculations are simplified:

- EC<sup>3</sup>, kg CO2 per Kg of are taken by default from "The Carbon Calculator" (Enviromental Agency, 2007) but in the cases there is not existing data. Then EC values are from ICE (BSRIA, 2011) or the manufacturer specifications.

<sup>&</sup>lt;sup>1</sup> Blower-door Test= measure of flow necessary to raise interior of a dwelling by 50 Pa Q<sub>50</sub> (McMullan, 2012)

<sup>&</sup>lt;sup>2</sup> 80% of the total roof area available- (Energy Saving Trust, 2015)

<sup>&</sup>lt;sup>3</sup> EC=Embodied Carbon

- "The Carbon Calculator" results have minor rounder errors as it is developed for mayor developments.
- Wall Areas has been worked out from Appendix A and Assignment Brief. To simplify calculation small walls of the single storey extension at the back have not been considered. Then, 4 wall areas of 5.1\*2.8 m are to be considered.
- When EC boundary is "Cradle to gate", transport to site, removal and disposal are calculated separately to achieve the "Cradle to grave" boundary required.
- Local providers have been chosen if available, in order to diminish further EC.
- When possible local recycle industries have been used. Otherwise, the Lamby Way Landfill has been selected as the as they use all non-recyclable materials for producing energy, Landfill gas (LFG), with the aim of reducing the systems footprint as much as possible.
- Average use of 20KWh per day in the worksite and a duration of works up to 2 weeks have been considered.
- An additional 10% of each material had been taken in account as "Waste on site" (Stevenson, 2020)
- The personnel travel is not accounted for the total EC by "The carbon Calculator" in the results shown in Appendix D by an error of the Excel, although they appear in the subtotals.

Then, the next two sections detail the systems and show the quantity of each materials that composed them, the manufacturers chosen and their location, the waste treatment method and any other relevant observation related to their EC emissions. Ultimately, the total EC of each system is stated. and the report from the carbon calculator with further details.

#### 10.1. Solution 1. Non-Breathable Wall Upgrade

### Option 1. KINGSPAN - PHENOLIC INSULATION - NON-BREATHBLE CONSTRUTION

Material	Manufacture	Location	Transport (Km)	Observations	Waste Treatment Method	Location	Transport (Km)
DPC Strips	Visqueen	Lundholm Rd, Ayrshire, Stevenston KA20 3NQ	721	B/ timber battens & stone wall. EC (BSRIA, 2011).	Landfill	Lamby Way Landfill. Rumney, Cardiff CF3 2HP	44.9
SCLEMS	Evolution	2A & 2B, Clyde Gateway Trade Park, Dalmarnock Rd, Rutherglen, Glasgow G73 IAN	661.4	600 mm centres. Stainless Steel Multi-Fix. Ref. A4CSK6.3-57-GP. Size:6.3 x 57mm. Assumed Steel General UK Average.	Recycle	Metal + Waste Recycling. Lightmoor Rd, Telford TF4 30N	175.4
Timber Battens Vertically	Al Timber Frame	Unit 43 Endeavour Cl,	00	600 mm centres	Recycle	Reseiclo Community Wood Recycling, The Woodstore,	
Timber Battens (Horizontal)	A1 Timber Frame	Purcell Ave, Port Talbot. SA 12 7PT	۵۵	Bottom/ top	Recycle	Alderney Street., Newport NP20 5NH	51.5
K118-Koltherm Insulation	Kingspan		-	Plasterboard and vapour barrier included . Embodied carbon from "Appendix No.ENP500at" (BRE,2020)	Landfill	Lamby Way Landfill. Rumney, Cardiff CF3 2HP	44.9
Windows Reveals. K118- Koltherm	Kingspan		-	Embodied carbon from "Appendix No.ENP50Dat" (BRE,2020)	Landfill	Lamby Way Landfill. Rumney, Cardiff CF3 2HP	44.9
Drywalls screws	Evolution	2A & 2B, Clyde Gateway Trade Park, Dalmarnock Rd, Rutherglen, Glasgow G73 IAN	661.4	300 mm centres along the perimeter of the boards. Min. depth 102.5+25mm. Number subjected to Insulation panel units per wall. Carbon Steel. Ref. DWSZI50. Size= 4.8*150mm. Assumed Steel General UK Average	Recycle	Metal + Waste Recycling. Lightmoor Rd, Telford TF4 3DN	175.4
Flexible polyutherane foam and flexible sealant	Flowstrip	Markham House, Atkinsons Way, Foxhills Industrial Park, Scunthorpe DN15 8QJ	402.3	Gun Grade Expanding PU Foam. Product Code: FASO909. Expansion is about 50 times. Joints between insulation board 10 mm and Lengths (refer to Kingspan data sheet). EC from ICE (BSRIA.2011)	Landfill	Lamby Way Landfill. Rumney, Cardiff CF3 2HP	44.9
Gyproc Drywall sealer	British Gypsum	Barrow Works, Loughborough LE12 8GB	280	Additional moisture resistance. 11/ 11sqm required. 2 layers. 51 required. WATER VAPOUR CONTROL. Density approx. = to general paint density.	Landfill	Lamby Way Landfill. Rumney, Cardiff CF3 2HP	44.9
White Clay Paint - Finished	Earthborn	Frodsham Business Centre, Bridge Lane, Frodsham, Cheshire WAG 7FZ	250	Lifestyle Paint. Water Based 61 / 60 sqm	Landfill	Lamby Way Landfill. Rumney, Cardiff CF3 2HP	44.9

Uption I. KINGSPAN - PHENOLIC INSULATION - NON-BREATHBLE CONSTRUTION												
Material	Width (mm)	Thickn ess (mm)	Lengths (mm)	Units	Valume (m3)	Density (tonnes/m 3)	Mass (tonnes)	Waste (tonnes)	Total (tonnes)	Boundary	CO2e (Kg CO2 / Kg).	CO2e (Kg CO2 / Kg). Related to boundary.
DPC Strips	47	0.5	134400.0	36	0.1137	0.92	0.1046	0.0105	0.1151	Cradle to gate	4.45	0.5120
SCLEMS				208	0.0004	7.8	0.0030	0.0003	0.0033	Cradle to gate	1.46	0.0048
Timber Battens Vertically	47	25.0	2800.0	36	0.1184	0.5	0.0592	0.0059	0.0651	Cradle to gate	0.31	0.0202
Timber Battens (Horizontal)	47	25.0	5100.0	8	0.0479	0.5	0.0240	0.0024	0.0264	Cradle to gate	0.31	0.0082
K118-Koltherm Insulation	1200	102.5	2400.0	20	5.9040	0.035	0.2066	0.0207	0.2273	Cradle to site	5.8	1.3184
Windows and door reveals. K118-Koltherm	450	32.5	30400.0	-	0.4446	0.035	0.0156	0.0016	0.0171	Cradle to site	5.8	0.0993
Drywalls screws				584	0.005	7.8	0.039	0.0039	0.0427	Cradle to gate	1.46	0.0624
Flexible polyutherane foam and flexible sealant	103	10	168000	-	0.0344	0.025	0.0009	0.00009	0.0009	Cradle to gate	4.06	0.0038
Gyproc Drywall sealer					0.005	1.2	0.006	0.0006	0.0066	Cradle to gate	0.13	0.0009
White Clay Paint - Finished					0.006	1.2	0.0072	0.00072	0.0079	Cradle to gate	2.54	0.0201

Option 1. KINGSPAN - PHENOLIC INSULATION - NON-BREATHBLE CONSTRUTION

Table 7

Sub-totals	tonnes CO <sub>2</sub> e	%
Quarried Material	0.0	0%
Timber	0.0	1%
Concrete, Mortars & Cement	0.0	0%
Metals	0.1	2%
Plastics	0.0	0%
Glass	0.0	0%
Miscellaneous	1.9	67%
Finishings, coatings & adhesives	0.0	1%
Plant and equipment emissions	0.0	0%
Waste Removal	0.1	2%
Portable site accommodation	0.1	4%
Material transport	0.0	0%
Personnel travel	0.6	22%

Table 8. "The Carbon Calculator" (Enviromental Agency, 2007)

Overall, this wall upgrade system based on phenolic insulation with 60 yeas of lifecycle is responsible for 2800 kg of CO<sup>2</sup> from cradle to grave (Appendix D). Being a half of the emmisions due to the insulation, having an enourmous impact, due to its artificial composition including plastics and the imposibility of recycle. Therefore, as there is not more sustainable insulation with the same properties the option to dinimish the EC of this systems are very limited.

		Option 2.	Rockwoo	JI - BREATHABLE CONSTRUCTION			
Material	Manufacture	Location	Transport (Km)	Observations	Waste Treatment Method	Location	Transport (Km)
Breather Membrane	Protect	002 Brooklands Station Approach, Cheshire, Sale M33 3SS	326	Law E Breather Membrane R = 0.77 m²K/W. Protect TF200 Thermo. Extruded Polypropylene. EC from ICE (BSRIA.2011)	Landfill	Lamby Way Landfill. Rumney, Cardiff CF3 2HP	44.9
Plywood	Al Timber Frame	Unit 43 Endeavour Cl, Purcell Ave, Port Talbot. SA 12 7PT	38	11kg/m2*10mm(Environmental Agency, 2007 )	Recycle	Reseiclo Community, Harlequin Trading Estate, Alderney Street, Newport NP20 5NH	51.5
Screws	Evolution	2A & 2B, Clyde Gateway Trade Park, Dalmarnock Rd, Rutherglen, Glasgow G73 IAN	661.4	300 centres along timber battens/ two rows at 400 centres to battens (service void)/ 300 centres along wood wool panels Ref. WST4035. 4.0 x 35mm.	Recycle	Metal + Waste Recycling. Lightmoor Rd, Telford TF4 3QN	175.4
Timber Battens Vertically	Al Timber Frame			400 mm centres		Reseiclo Community Wood	
Timber Battens (Horizontal)	A1 Timber Frame	Unit 43 Endeavour Cl, Purcell Ave, Port Talbot. SA 12 7PT	38	Tap/ Battam	Recycle	Recycling, The Woodstore, Harlequin Trading Estate, Alderney Street Newnort	51.5
Timber Battens (Horizontal)	Al Timber Frame		38	service Void 25 mm - 5 horizontal battens - Wood wool boards fixed on to them		NP2D 5NH	
Kockwool Flexi	Rockwool	Irrelevant	-	Between studs- 85% of Wall area	Recycle	Rockwool Recycling Facility	
Option B- Wood wool boards	CELENIT	JRM5+38 Tombolo, Province of Padua, Italy	-	Celenit N. EC from Specifications. (Celenit S.p.A., 2020)	Landfill	Lamby Way Landfill. Rumney, Cardiff CF3 2HP	44.9
Breathaplasta	Adaptavate*	Unit 10 button Mills Industrial Estate, Lower Mills, Stonehouse, Gloucestershire, GLID 288	112.2	Lime based product. Lime plasta Finished. 4mm Thickness - 20kg - 5 sqm (57 sqm to cover ). Embodied Carbon of Lime from ICE (BSRIA,2011)	Landfill	Lamby Way Landfill. Rumney, Cardiff CF3 2HP	44.9

# 10.2. Solution 2. Breathable Wall Upgrade

				Optio	n 2. Ro	ckwool - B	REATHABL	E CONSTR	UCTION			
Material	Width (mm)	Thickn ess (mm)	Lengths (mm)	Units	Volume (m3)	Density (tonnes/m 3)	Mass (tonnes)	Waste (tonnes)	Total (tonnes)	Boundary	CO2e (Kg CO2 / Kg)	CD2e (Kg CD2 / Kg). Related to boundary.
Breather Membrane	5100	0.5	2800.0	4	0.0274	0.33	0.0090	0.0009	0.0100	Cradle to Gate	4.98	0.0496
Plywood	5100	10.0	2800.0	4	0.5712	0.55	0.3142	0.0314	0.3456	Cradle to Gate	0.45	0.1555
Screws				1772	0.0031	7.8	0.0243	0.0024	0.0267	Cradle to gate	1.46	0.0390
Timber Battens Vertically	22	140.0	2800.0	52	0.4484	0.5	0.2242	0.0224	0.2466	Cradle to Gate	0.31	0.0765
Timber Battens (Horizontal)	22	140.0	5100.0	8	0.1257	0.500	0.0628	0.0063	0.0691	Cradle to Gate	0.31	0.0214
Timber Battens (Horizontal)	47	25.0	5100.0	20.00	0.1199	0.500	0.0599	0.0060	0.0659	Cradle to Gate	0.31	0.0204
Rockwool Flexi Insulation		140.0			6.230	0.0	0.280	0.0280	0.3084	Cradle to grave	1.2	0.3701
Option B- Wood wool boards	600	15	2400	39	0.8424	0.53	0.4465	0.04465	0.4911	Cradle to site	1.38	0.6777
Breathaplasta	600		4				0.228	0.0228	0.2508	Cradle to Gate	0.76	0.1906
-Table 9												

tonnes CO <sub>2</sub> e	%
0.2	8%
1.0	40%
0.0	0%
0.0	2%
0.0	2%
0.0	0%
0.1	6%
0.0	0%
0.0	0%
0.4	16%
0.0	0%
0.0	0%
0.6	26%
	tonnes CO <sub>2</sub> e 0.2 1.0 0.0 0.0 0.0 0.0 0.1 0.0 0.0 0.0 0.0

Table 10. "The Carbon Calculator" (Enviromental Agency, 2007)

In this option, the extremely low EC of the rockwool insulation, due to its natural condition and the possibility of recycling,  $(138 \text{ Kg CO}_2)$  makes possible a reduction overall of 400 kg CO<sub>2</sub> from the previous system, with a total EC of 2400kg CO<sub>2</sub>. However, the savings are not larger due to the greater use of wood to create a self-supported frame and the use of plywood on the outer side and the inner wood board, which altogether produces 40% of the total EC. However, for future retrofits an alternative use of cork (0.19 kg CO<sub>2</sub>/Kg (BSRIA, 2011)) and 0.24 Tonnes/m3 instead of plywood; or a Lime Breathable plasterboard from Adaptavate (2020) has potential to reduce further the EC of this system. The last elements is not as yet in the market but it has been use on "The UK Green building Council" where EC was reduced by 22% from the standards (Adaptavate, 2020) and also it is a local product unlike the wood boards.

#### 10.3. Comparison

Finally, when comparing the advantages and drawbacks of both systems, the breathable wall upgrade with rockwool insulation is more beneficial for this retrofit. This is because it involves less damp risk at the time the wall system EC emissions are lower and its lifecycle longer whilst the only advantage of the phenolic insulation system is its thickness. However, in this case even if it is tight the rockwool insulation option still leaves an acceptable 75 sqm area for a 3 people dwelling.

SYSTEM	EC (KG CO2) "CRADLE TO	LIFECYCLE <sup>1</sup> (Years)	AREA REDUCTION (sqm)
	GRAVE"		Current Total area = 80
Non-Breathable. Kingspan	2400	60	77.4
Breathable. Rockwool	1800	75	75.35

#### Table 11

## 5. <u>Conclusions. OC<sup>2</sup> vs EC<sup>3</sup></u>

This paper has developed with success a feasible and cost-effective retrofit plan for a pre-1919 house that achieves the 95% reduction of CE claimed by the Wales government for 2050. Therefore, it is verified that the goal is achievable through a holistic "First fabric" approach rather than by the introduction of individual. Furthermore, the coordination of all strategies within the plan is essential for its success together with a minimisation of risks

On the other hand, it has been explored the impact on the EC footprint of the building caused by the upgrade strategy, as if it is true that it brings a massive reduction of the building OC emissions, the new elements have inherent CE which diminishes the carbon savings. Then, the study of the wall upgrade has quantified that impact in the retrofit, which it is subjected to be diminished by future studies of the material utilized within the system in order to decrease the overall EC.

All in all, it is considered successful the results obtained along this research as OC has been reduced from 3256 to 400 Kg  $CO_2$  a year through "The "8" retrofit and "The Rockwool Breathable Wall System" only adds 2400 Kg  $CO_2$  while is

<sup>&</sup>lt;sup>1</sup> Data from Insulation Manufacturer. It is assumed as the whole wall system lifecycle for the purpose of this document.

<sup>&</sup>lt;sup>2</sup> Operational Carbon

<sup>&</sup>lt;sup>3</sup> Embodied Carbon

responsible for 11% of the OC reduction. That is, it is saving 784 Kg  $CO_2$  per year, which is 58800 Kg  $CO_2$  along its 75-year lifecycle, with a payback period of 3'06 years, only the 4% percent of the system lifecycle.

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## 7. <u>Appendix A – Floor Plans.</u>



Figure 1. Floor plans provided by Lannon, S ( 2020) in "SAP Workshop"

Dimensions shown have been taken as inner referential dimensions

## 8. Appendix B - Retrofit "8" - SAP Model



Figure 2. SAP MODEL Results. (CRIBE, 2014)

## 9. Appendix C- PV-Panels Details from Manufacture.





Nominal Power (Pmax)	380W	385W	390W	395W	400W
Open Circuit Voltage (Voc)	48.6V	48.8V	49V	49.2V	49.3V
Short Circuit Current (lsc)	10.26A	10.35A	10.44A	10.53A	10.65A
Voltage at Nominal Power (Vmp)	40.4V	40.6V	40.8V	41V	41.2V
Current at Nominal Power (Imp)	9.42A	9.5A	9.57A	9.64A	9.72A
Module Efficiency (%)	19.28	19.53	19.79	20.04	20.29
Operating Temperature		-40°C t	:o +85°C		
Maximum System Voltage		1000V / 150	DOV DC(IEC)		

#### Maximum Series Fuse Rating

\*STC:Irradiance 1000W/m², module temperature 25, AM=1.5 Optional black frame or white frame module according to customer requirements

#### **ELECTRICAL CHARACTERISTICS AT NOCT**

Nominal Power (Pmax)	281W	285W	289W	293W	296W
Open Circuit Voltage (Voc)	45.9V	46.1V	46.3V	46.5V	46.6V
Short Circuit Current (Isc)	8.28A	8.36A	8.43A	8.5A	8.6A
Voltage at Nominal Power (Vmp)	38.2V	38.4V	38.6V	38.7V	38.9V
Current at Nominal Power (Imp)	7.36A	7.42A	7.49A	7.57A	7.61A
*NOCT : Irradiance 800W/m² ambient temperature 20°C	wind cnoo	d 1 m/c			

/m², ambient temperature 20℃, wind speed 1 m/s

## **MECHANICAL CHARACTERISTICS**

Cell Type	Monocrystalline 156.75 × 78.375mm
Number of Cells	144 (6 × 24)
Module Dimensions	1987mm×992mm×40mm
Weight	23.0kg
Front Cover	High transmission tempered glass
Frame	Anodized aluminium alloy
Junction Box	IP67
Cable	4mm² (IEC)
	the street a street a

## **TEMPERATURE CHARACTERISTICS**

15A

PACKAGING	
Temperature Coefficient Of Isc	0.049%/K
Temperature Coefficient Of Voc	-0.29%/K
Temperature Coefficient Of Pmax	-0.39%/K
Nominal Operating Cell Temperature (NOCT)	45°C + 2°C

Standard Packaging	26 pcs / Pallet
Module Quantity per 40' Container	572pcs

Connector

MC4 / MC4 Compatible



Specifications in this datasheet are subject to change without prior notice. Also available in all-black.

## **IV CURVES**



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# 10. Appendix D- Carbon Calculator calculations and reports

#### 10.1. Option 1. NON-BREATHABLE. Kingspan.

	tal CarbonFootprint:		2	tonnes fossil	CO <sub>2</sub> e		
Conversio	on (miles to km)	Miles	Kilometres				
	,,	32.00	51.5				
iterial qu	antities shoul	d be entere	d in tonnes (	except w	here no	oted)	
conversion co	olumn will help users to	calculate tonnage	e, but it is up to users	to make the ca	lculation ar	d enter the	tonnage the
						s of	
						ource	
Category	Construction	material	Unit Conversion	tCO <sub>2</sub> e per	(sa	en s (km	ort
outogory	Constitution	- material	or Density	tonne of material	tom	betwo d site	ransp
					ntity	ance oly ar	e of t
					Qua	Dist supl	pow
Quarried	Quarried aggregate		2.0 tonnes/m3	0.005			
Material	Recycled aggregate Marine aggregate		2.0 tonnes/m3 2.0 tonnes/m3	0.005			
	Asphalt, 4% (bitumer	n) binder content	1.7 tonnes/m3	0.066			
	(by mass) Asphalt 5% (bitumer	) binder content	1.7 topper/m3	0.071			
	Asphalt, 5% (bitume	) blader content	1.7 tonnes/m3	0.07			
	Asphalt, 6% (bitumer	n) binder content	1.7 tonnes/m3	0.076			
	Asphalt, 7% (bitumer	n) binder content	1.7 tonnes/m3	0.081			
	Asphalt, 8% (bitumer	n) binder content	1.7 tonnes/m3	0.086			
	Bitumen Bricks		2.4 tonnes/m3 1.9 tonnes/m3	0.490			
	Clay: general (simple	baked products)	1.9 tonnes/m3	0.240			
	Clay tile	,	2.4 tonnes/m3	0.480			
	Vitrified clay pipe DN	100 & DN 150	2.4 tonnes/m3	0.460			
	Vitrified clay pipe DN	200 & DN 300	2.4 tonnes/m3	0.500			
	Vitrified clay pipe DN	500	2.4 tonnes/m3	0.550			
	Ceramics: general Ceramics: Tiles and	Cladding Panels	1.9 tonnes/m3 2.2 tonnes/m3	0.700			
	Sand	ad aall	1.2 tonnes/m3	0.005			
	Stone: general / ramm	ed soll	1.7 tonnes/m3 2.0 tonnes/m3	0.024			
	Granite		2.9 tonnes/m3	0.700			
	Sandstone		2.2 tonnes/m3 2.2 tonnes/m3	0.090			
	Shale		2.7 tonnes/m3	0.002			
	Siate Sub-total		1.6 tonnes/m3	0.035	(		
					-		
Timber	Glue laminated timber	n	0.5 tonnes/m3 0.5 tonnes/m3	0.310	0	38	Road
	Hardboard		26.0 kg/m2*20mm	0.580			
	Oriented Strand Boa		14 kg/m2*20mm	0.390			
		rd (OSB)	T tormes/m3	0.450		-	
	Particle Board	rd (OSB)	6 kg/m2*20mm	0.450			
	Particle Board Plywood Reclaimed timber	rd (OSB)	6 kg/m2*20mm 11 kg/m2*20mm 1 tonnes/m3	0.450 0.540 0.450 0.031			
	Particle Board Plywood Reclaimed timber Sawn Hardwood	rd (OSB)	6 kg/m2*20mm 11 kg/m2*20mm 1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3	0.450 0.540 0.450 0.031 0.240 0.200			
	Particle Board Plywood Reclaimed timber Sawn Hardwood Sawn Softwood <b>Sub-total</b>	rd (OSB)	6 kg/m2*20mm 11 kg/m2*20mm 1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3	0.450 0.540 0.450 0.031 0.240 0.200			
	Particle Board Plywood Reclaimed timber Sawn Hardwood Sawn Softwood Sub-total	rd (OSB)	6 kg/m2*20mm 11 kg/m2*20mm 1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3	0.450 0.540 0.450 0.031 0.240 0.200			
	Particle Board Plywood Reclaimed timber Sawn Hardwood Sawn Softwood Sub-total	rd (OSB)	6 kg/m2*20mm 11 kg/m2*20mm 11 kg/m2*20mm 1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3 Unit Conversion or Density	0.450 0.540 0.450 0.031 0.240 0.200 tCO <sub>2</sub> e/t or unit	Tonnage	Distance	Mode
Metals	Particle Board Plywood Reclaimed timber Sawn Hardwood Sawn Softwood Sub-total	rd (OSB)	6 kg/m2*20mm 1 kg/m2*20mm 1 kg/m2*20mm 1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3 Unit Conversion or Density 8.9 tonnes/m3	0.450 0.540 0.031 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.71	Tonnage or unit	Distance	Mode
Metals	Particle Board Plywood Reclaimed timber Sawn Hardwood Sawn Softwood Sub-total Copper: EU Tube & S Copper: Reused cop	sheet	6 kg/m2*20mm 11 kg/m2*20mm 11 kg/m2*20mm 10 connes/m3 0.6 tonnes/m3 0.5 tonnes/m3 Unit Conversion or Density 8.9 tonnes/m3 8.9 tonnes/m3	0.450 0.540 0.031 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.71 0.27	Tonnage or unit	Distance	Mode
Metals	Particle Board Plywood Reclaimed limber Sawn Hardwood Sawn Softwood Sub-total Copper: EU Tube & C Copper: Reused copp Iron	oneet	Ginesins     Gagner20mm     Isonesim3     Gagner20mm     Isonesim3     Gatonesim3     Ostonnesim3     Sytonesim3     Sytonnesim3     Agtonnesim3     Agtonnesim3     Targenesim3	0.450 0.540 0.031 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.77 0.27 2.03 160	C Tonnage or unit	Distance	Mode
Metals	Particle Board Plywood Reclaimed limber Sawn Hardwood Sawn Softwood Sub-total Copper: EU Tube & C Copper: Reused cop tron Ten Steel: General - UK (	rd (OSB) sneet ber EU) Average	Gright220mm 11 kg/m220mm 1 kg/m220mm 1 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 8.9 tonnes/m3 8.9 tonnes/m3 11.34 tonnes/m3	0.450 0.540 0.033 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.77 0.27 2.05 1.06 1.44	Tonnage or unit	Distance	Mode
Metals	Particle Board Plywood Reclaimed timber Sawn Jardwood Sawn Softwood Sub-total Copper: EU 100e & 1 Copper: Reused cop trion Lead Steel: General - UK ( Recycled Content -	rd (OSB) sneet ber EU) Average (EU) Average	Connesimo     Gigine220mm     It kg/m220mm     It connes/m3     Co 6 tonnes/m3     O.5 tonnes/m3     Stonnes/m3     Stonnes/m3     Stonnes/m3     T.8 tonnes/m3     T.8 tonnes/m3	0.450 0.450 0.450 0.450 0.450 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.77 0.27 2.03 1.60 1.44	Tonnage or unit 0	Distance	Mode
Metals	Particle Board Piywood Reclaimed timber Sawn Hardwood Sawn Schwood Sub-total Copper: EU 1056 & 1 Copper: Reused cop tron Lead Steel: General - UK Recycled Content Recycled Content Steel: Cont (Sheet, C.	oneet per EU) Average (EU) Average alvanised - UK	Gomesina Geogrammeter Commendation     Geogrammeter Commendat	0.450 0.450 0.450 0.450 0.240 0.200 tCO3e/t or unit 2.77 2.03 1.66 1.46 1.40	Tonnage or unit	Distance	Mode
Metals	Particle Board Piywood Reclaimed timber Sawn Hardwood Sawn Softwood Sub-total Copper: EU 1056 & 3 Copper: Reused cop Iron Lead Steel: Ganeral - UK Recycled Content Recycled Content Steel: Sar of - UK Recycled Content Steel: Can (Sheet), G	sheet EU) Average EU) Average (EU) Average alvanised - UK ed Content	Golinesina Golinesina Golinesina Golinesina Golinesina Golinesina Golinesina Golinesina Golinesina Golinesina Golinesina Conversion or Density Sufonesina Soforesina Conversion or Density Sufonesina Conversion or Density Sufonesina Conversion Or Density Sufonesina Conversion Or Density Sufonesina Conversion Conversion Or Density Sufonesina Conversion Conversion Or Density Sufonesina Conversion Conversion Or Density Sufonesina Conversion Conversion Conversion Conversion Or Density Sufonesina Conversion Conversio	0.450 0.455 0.0540 0.240 0.240 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.450 0.450 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.455 0.240 0.2100 0.210000000000	Tonnage or unit	Distance	Mode
Metals	Particle Board Piywood Reclaimed limber Sawn Hardwood Sawn Softwood Sub-total Copper: EU 1068 & 3 Copper: Reused copt ron Lead Stati: Generic - UK Recycled Content Recycled Con	shéet EU) Average (EU) Average d'Content UK ed Content UK el - Recycled awaren Denuet	Gormannia Santa San	0.450 0.455 0.037 0.240 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.200 0.455 0.2400 0.200 0.200 0.200000000	Tonnage or unit	Distance	Mode
Metals	Particle Board Physicod Reclaimed timber Sawn Hardwood Sub-total Copper: Reused cop Iron Recycled Content Steel: General - UK Steel: General - UK Steel: General - UK Steel: Engineering st Steel: Engineering st Steel: Engineering st Steel: Engineering st	d (OSB) sheet EU) Average (EU) Average (EU) Average alvanised - UK d Content Pel - Recycled Average Recycle	Conversion     Gaym2/20mm     It kg/m2/20mm     It kg/m2/20mm     It sonnes/m3     O.6 tonnes/m3     O.6 tonnes/m3     O.5 tonnes/m3     S.9 tonnes/m3     R.9 tonnes/m3     R.9 tonnes/m3     R.8 tonnes/m3     R tonnes/m3     R tonnes/m3     R tonnes/m3     R tonnes/m3     R tonnes/m8     R tonnes/m8     R tonnes/m8     R tonnes/m8     R tonnes/m8	0.450 0.544 0.450 0.033 0.244 0.200 tCO <sub>2</sub> e/t or unit 2.77 0.27 0.27 0.27 1.6 1.4 1.4 1.5 0.77 1.4	Tonnage or unit	Distance	Mode
Metais	Particle Board Phymood Reclaimed timber Sawn Hardwood Sub-total Copper: Reused cop tron Eagle Content Steel: Tope-UK (EU).	offeet ber EU) Average (EU) Average de Content sel - Rocycled Average Recycle Average	Conversion     C	0.450 0.544 0.450 0.200 0.200 tCO <sub>20</sub> t or unit 2.77 0.21 0.20 0.20 0.200000000	Tonnage or unit	Distance	Mode
Metals	Particle Board Plywood Reclaimed timber Sawn Hardwood Sub-total Copper: Reused cop Ton Lead Steel: Ceneral - UK ( Recycled Content Steel: Seneral - UK ( Recycled Content Steel: Seneral - UK ( Recycled Content Steel: Plan-LW (EU) Content Steel: Plan-LW (EU) Content Steel: Sections - UK	d (OSB) sheet ber EU) Average alvanised - UK d Content bei - Recycle Average Recycle Average EU) Average	Gormannia Service Commentation     General Comment     General Commentation     Genera Commentation     Genera Comme	0.455 0.544 0.455 0.204 tCO <sub>20</sub> /t or unit 2.77 0.27 2.05 1.69 1.46 1.46 1.55 1.66 1.15	Tonnage or unit	0istance	Mode
Metals	Particle Board Plywood Reclaimed timber Sawn Hardwood Sub-total Sub-total Copper: EU 100e & 1 Copper: Reused cop tron Lead Steel: Ceneral – UK ( Recycled Content Steel: Seneral – UK (EU Recycled Content Steel: Plane-UK (EU) Steel: Steel: St	d (OSB) oneet EU) Average (EU) Average alvanised - UK d Content alvanised - UK d Content alvanis d Content alvanised - UK d Content alvanised - UK	Gormannia (Georgia)     Gormannia (Georgia)     Georgia (Georgia)     Georgia (Georgia)     Georgia (Georgia)     Georgia     Georgia)     Georgia     Georgi	0.450 0.544 0.450 0.200 0.200 tCO <sub>2</sub> eft or unit 2.77 0.27 2.05 1.55 1.55 1.55 1.55 1.55 1.55 1.55 1	Tonnage or unit	0istance	Mode
Metals	Particle Board Piywood Reclaimed timber Sawn Hardwood Sub-total Copper: EU 1006 3: Copper: Reused con Ton Lead Steel: Ceneral - UK (CU Recycled Content Steel: Send Content Steel: Send Content Steel: Send Content Steel: Pipe-UK (EU) Content Steel: Pipe-UK (EU) Content Steel: Pipe-UK (EU) Content Steel: Pipe-UK (EU) Content Steel: Steel: Conton - UK (EU) Content Steel: Steel: Conton - UK (EU) Content Steel: Steel: Staineering at Steel: Steel: Staineering at Steel: Staineering at St	oneet EU) Average EU) Average EU) Average el Col Average el Recycled Average Recycled Average	Conversion     C	0.450 0.544 0.545 0.200 0.200 tCO <sub>2</sub> eft or unit 2.77 0.27 2.00 7.27 0.27 2.00 1.59 1.59 1.50 1.50 1.50 1.55 1.55 1.55 1.55 1.55	Tonnage or unit	0istance	Mode
Motais	Particle Board Piywood Reclaimed timber Sawn Hardwood Sub-total Copper: EU 1105 & 1 Copper: Reused cop tron Lead Steel: Ceneral - UK (Recycled Content Steel: Caneral - UK (Recycled Content Steel: Steel:	eneet EU) Average EU) Average et CU) Average et CU) Average et Cu) Average EU) Average EU) Average	Conversion     Gegin2/20mm     Ekgin2/20mm     It kg/m2/20mm     It kg/m2/20mm     It connes/m3     O f tonnes/m3     O f tonnes/m3     O f tonnes/m3     Stonnes/m3     Stonnes/m3     R tonnes/m3     R	0.455 0.544 0.455 0.244 0.200 tCO <sub>2</sub> eft or unit 2.77 0.27 0.27 0.27 0.27 0.27 0.27 0.27	C Tonnage or unit	Distance	Road
Metais	Particle Board Physocol Reclaimed Imber Sawn Flardwood Sub-total Copper: Reused cop Tron Teor Recycled Content Steel: General – UK Steel: General – UK Steel: General – UK Steel: General – UK Steel: Saw & col – UK Recycled Content Steel: Engineering at Steel: Engineering at Steel: Pare – UK (EU) Steel: Engineering at Steel: Steel: Salicies Steel: Steel: Salicies Steel: Steel: Steel: Steel: Steel: Steel: Steel: Steel: Steel: Steel: Steel: Steel: St	er (OSB) snieet EU) Average EU) Average el - Recycled Average EU) Average EU) Average	Conversion     C	0.450 0.544 0.450 0.031 0.244 0.200 2.77 0.27 2.05 2.75 2.05 1.65 1.65 1.65 1.65 1.65 1.65 1.65 1.6	C Tonnage or unit	Distance	Mode
Motais	Particle Board Physicod Reclaimed timber Sawn Fartwood Sub-total Copper: Reused cop tron Copper: Reused cop tron Steel: General – UK Steel: General – UK Racycled Content Steel: General – UK Racycled Content Steel: Content Steel: Engineering st Steel: Engineering st Steel: Engineering st Steel: Engineering st Steel:	d (OSB) offeet ber EU) Average EU) Average d Content sel - Recycled Average EU) Average EU) Average EU) Average with fittings	Contesting     C	0.450 0.544 0.544 0.200 0.200 0.200 0.200 0.200 0.27 2.00 2.7 2.00 1.05 1.44 1.44 1.55 0.77 1.44 1.55 0.77 0.77 1.44 1.55 0.77 0.77 0.77 0.77 0.77 0.77 0.77 0	Consee or unit	Distance 661	Mode Road
Metals	Particle Board Physicod Reclaimed timber Sawn Hardwood Sub-total Copper: Reused cop Ton Lead Steel: Ceneral - UK ( Recycled Content Steel: Ceneral - UK ( Recycled Content Steel: Ceneral - UK ( Recycled Content Steel: Content Steel: Content Steel: Content Steel: Sectors - UK Recycled Content Steel: Sectors - UK	d (OSB) sheet ber EU) Average EU) Average diverage Average el - Recycle Average EU) Average el - Recycle Average el - Recycle - Recy	tornes/m3           6 kg/m2:20mm           11 kg/m2:20mm           11 kg/m2:20mm           11 tornes/m3           0.5 tornes/m3           0.5 tornes/m3           0.6 tornes/m3           0.7 stornes/m3           1.34 tornes/m3           7.8 tornes/m3           7.9 tornes/m3           7.0 tornes/m3           7.0 tornes/m3           7.10 tornes/m3	0.450 0.544 0.450 0.033 0.240 0.200 0.200 0.27 0.27 0.27 0.27 0.27 0	C C C C C C C C C C C C C C C C C C C	Distance	Road
Metals	Particle Board Plywood Reclaimed timber Sawn Hardwood Sub-total Copper: Reused cop Ton Lead Steel: Ceneral - UK ( Recycled Content Steel: General - UK ( Recycled Content Steel: General - UK ( Recycled Content Steel: Flars Arod - UK Recycled Content Steel: Plar-UK (EU) Content Steel: Plar-UK (EU) Content Steel: Read Content Steel: Recycled Content Steel: Steelinering at Steel: Plar-UK (EU) Content Steel: Steelinering at Steel: Read Content Steel: Steelinering at Steel: Steelinering at Steel: Steelinering at Steel: Steelinering at Steel: Read Content Steel: Steelinering at Steel: Steelinering at Steel: Read Steel Aluminium: Read Aluminium: Rotted Handrait: stainless st Handrait: stainless st	d (OSB) sheet ber EU) Average EU) Average alvanised - UK d Content bel - Recycled Average Recycle Average EU) Average with fittings sel wilded	Ginasins     Gigin2:20mm     It kg/m2:20mm     It kg/m2:20mm     It kg/m2:20mm     It onnes/m3     O 5 tonnes/m3     O 5 tonnes/m3     S tonnes/m3     S tonnes/m3     A tonnes/m3     T.8 tonnes/m3     7.8 tonnes/m3     0.0115 tonnes/m     0.0115 tonnes/m	0.450 0.544 0.450 0.030 0.200 0.200 0.200 0.27 0.27 0.27 0.27	0	Bistance Bistance Bistance	Road
Motals	Particle Board Plywood Reclaimed timber Sawn Hardwood Sub-total Copper: Reused cop Ton Lead Steel: Ceneral - UK ( Recycled Content Steel: Seneral - UK ( Recycled Content Steel: Recycled Content Steel: Sectors - UK ( Recycled Content Steel: Reused steel Aurinium: Refued Handrait: stainless st Handrait: stainless st	d (OSB) oneet ore EU) Average EU) Average alvanised - UK d Content eU - Recycled Average Recycle Average EU) Average with fittings el with fit	Conversion     C	0.450 0.544 0.544 0.200 0.200 0.200 0.200 0.27 0.27 0.27	0	661	Mode
Motais	Particle Board Piywood Reclaimed timber Sawn Jarkwood Sub-total Sub-total Copper: EU 1006 3: 1 Copper: Reused copies Ton Lead Steel: Central - UK (EU) Content - UK (EU) Conte	eneet U) Average U) Av	Conversion     C	0.450 0.544 0.544 0.450 0.200 0.200 0.200 0.200 0.200 0.200 0.27 0.27	0	Bistance Bistance	Mode Road
Motals	Particle Board Physicod Reclaimed timber Sawn Flardwood Sub-total Copper: Reusel dog Ton Ton Teaching Content Steel: Content Steel: General – UK Steel: General – UK Recycled Content Steel: General – UK Steel: Content Steel: Engineering at Steel: Parke – UK (EU Recycled Content Steel: Engineering at Steel: Parke – UK (EU Recycled Content Steel: Steel: Parke – UK (EU Recycled Content Steel: Steel: Steller Recycled Content Steel: Steller Steel: Steller Recycled Content Steel: Steller Steel: Steller Stell	eneet EU) Average EU B E E E E E E E E E E E E E E E E E E	Connes/m3     Conversion     Co	0.455 0.544 0.455 0.031 0.244 0.200 1.27 0.27 0.27 0.27 0.27 1.57 1.44 1.44 1.44 1.44 1.55 0.77 1.45 1.55 0.11 1.55 0.11 9.16 9.03 9.01 9.01 9.01 9.01 9.01 9.01 9.01 9.01	0		Mode Road
Motais	Particle Board Physood Reclaimed timber Sawn Sdrwood Sub-total Copper: Reu lube & 1 Copper: Reused cop Iron Steel: General – UK Steel: Solicitation Steel: Solicitation Solicitation Solicitation Steel: Solicitation Steel: Solic	d (OSB) offeet ber EU) Average (EU) Average el Content bel - Recycled Average Recycle Average EU) Average EU) Average el with fittings bel with fittings bel with fittings bel weided ; se on 150 & DN 300	Contesting     Conversion     C	0.455 0.544 0.455 0.031 0.244 0.200 0.200 2.7 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0	0	Distance 661	Mode Road



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> Footprint (tonnes fossil CO<sub>2</sub>e) mbodied Transport Sum

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0.	0.0	0.6
0.	0.0	0.0
0.	0.0	0.0
0.	0.0	0.0
0.06	0.0	0.072
0.06	0.003	0.0
0.06	0.003	0.0
0.06	0.003	0.0
0.06	0.003	0.0
0.06	0.00	0.0
0.00	0.03	0.07
0.06	0.03	0.0
0.00	0.03	0.072
0.00	0.003	0.072
0.06	0.003	0.072
0.06	0.003	0.072
0.06	0.003	0.0
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0.66		
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0.06		
0.06		
0.08		

		1		1				1
Title of projects								
Construction cost:	-	1		1				
Total Carbon Footprint:	2.2	tonnes foss	I CO2e					
							·	
-	We would like to hear from you	1:		/				
We would like to build a databas	se of case studies on the EA website to	share knowled	ge, emission reduction			ппе		
Please send your completed as	amples tecc@environment.agency.gov	uk Do not fora	et to include a chort					
description of the actions / mea	sures you have identified for the reducti	on of the total o	arbon footprint in the			-		
Preject Information page.		1			Agency			
- Bernannel travel							L	
Personnei traver					© Environment Agency			
H					copyright and/or database right 2007			
Material transport	0				All rights reserved			
H							<u> </u>	
- Bertable site								
accommodation	0			<u> </u>	Sub-totals	tonnes CO <sub>2</sub> e	%	
					Quarried Material	0.0	1%	
Waste Removal	0				Concrete, Mortars & Cement	0.0	0%	
H					Metals	0.1	2%	
Plant and equipment					Plastics	0.0	0%	
emissions	0				Glass Miscellaneous	0.0	67%	
H_					Finishings, coatings & adhesives	0.0	1%	
Finishings, coatings &	d		_	-	Plant and equipment emissions	0.0	0%	
adhesives					Waste Removal	0.1	2%	
Н					Portable site accommodation	0.1	4%	
Miscellaneous			2		Material transport	0.0	0%	
Н				<u> </u>		0.6	2270	<u> </u>
Glace	a							
Ц	1							
Н								
Plastics	q			L	Significant materials (figures include transport to site)		1	
Metals	0							
Concrete, Mortars &								
Cement	U							
Н							+	
Timber	0							
Quarried Material	0							
-	•	~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	/				
	Tonnes CO <sub>2</sub>	e						
							1	
H		1	I	·	Site accommodation - Grid electricity	0.119	tonnes CO2e	
F								
- The accuracy of individual valu	es is unlikely to be better than +/-5%. A	s a consequen	ce of using default					<u> </u>
+/-25% of the true value. Giver	the range of values associated with c	ertain materials	(cements for example		K118- Koltherm insulation	1.415	tonnes CO2e	
derault values may give results	unar are out by 100% or more. Local d	ata should be t	peu wnere available.					
		-			Poliurethane, Flexible Foam	0.004	tonnes CO2e	
				L		0.004	L	L
		-		-				-
		1		L				
				<u> </u>				
	-	-						
				-				
		+						
		1						<u> </u>
					Waterborne paint	0.020	tonnes CO2e	
H								
	-	1		1	Damp Proof Course/Membrane	0.521	tonnes CO2e	
							L	
		-						<u> </u>
		1						
Ц.								
Plaster: gene	eral (Gypsum)	+		1				
								<u> </u>
				<u> </u>				
	-	1		1				

## 10.2. Option 2. BREATHABLE. Rockwool.

÷-	Construction Cost:	0	2	tonnos fee-"	CO c		
То	tai CarbonFootprint:		2	connes fossil	CO26		
Conversi	on (miles to km)	Miles	Kilometres	]			
		0.00	0.0	l			
terial qu conversion o	Iantities shoul plumn will help users to	d be entere	ed in tonnes ( e, but it is up to users	except w to make the ca	here no	<b>oted)</b> nd enter the t	onnage the
Category	Constructio	n material	Unit Conversion or Density	Embodied tCO <sub>2</sub> e per tonne of material	Quantity (tonnes)	Distance between source of supply and site (km)	Mode of transport
			-				
Quarried Material	Quarried aggregate Recycled aggregate		2.0 tonnes/m3 2.0 tonnes/m3	0.005			
	Marine aggregate		2.0 tonnes/m3	0.008			
	Asphalt, 4% (bitumer (by mass)	n) binder content	1.7 tonnes/m3	0.066			
	Asphalt, 5% (bitume	n) binder content	1.7 tonnes/m3	0.071			
	Asphalt, 6% (hitume	n) binder content	1.7 topnes/m3	0.074			
	Aenha# 70/ /Lik	n) hinder ec-t	1.7 tor/ ^	0.070			
	Aspnalt, 7 % (Ditume)	, under content	1.7 tonnes/m3	0.081			
	Asphalt, 8% (bitumer	a) binder content	1.7 tonnes/m3	0.086			
	Bitumen Bricks		2.4 tonnes/m3 1.9 tonnes/m3	0.490			
	Clay: general (simple	e baked products)	1.9 tonnes/m3	0.240			
	Clay tile	. ,	2.4 tonnes/m3	0.480			
	Vitrified clay pipe DN	1 100 & DN 150	2.4 tonnes/m3	0.460			
	Vitrified clav pipe DN	200 & DN 300	2.4 tonnes/m3	0.500			
	Vitrified clay pipe DN	500	2.4 tonnes/m3	0.550			
	Ceramics: general	Cladding Panels	1.9 tonnes/m3	0.700			
	Sand	g	1.2 tonnes/m3	0.005			
	Soil - general / ramm Stone: general	ied soil	1.7 tonnes/m3 2.0 tonnes/m3	0.024			
	Granite		2.9 tonnes/m3	0.700			
	Limestone		2.2 tonnes/m3	0.090			
	Shale		2.2 tonnes/m3 2.7 tonnes/m3	0.002			
	Slate		1.6 tonnes/m3	0.035			
	Sub-total				(		
Timber	Timber: general		0.5 tonnes/m3	0.310	0	38	Road
	Glue laminated timbe Hardboard	3r	0.5 tonnes/m3 26.0 kg/m2*20mm	0.420			
	MDF		14 kg/m2*20mm	0.390			
	Oriented Strand Board	rd (OSB)	1 tonnes/m3 6 kg/m2*20mm	0.450			
	Plywood		11 kg/m2*20mm	0.010	0	38	
	Reclaimed timber			0.450			Road
	Cours Hordwood		1 tonnes/m3	0.450			Road
	Sawn Hardwood Sawn Softwood		1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3	0.031			Road
	Sawn Hardwood Sawn Softwood Sub-total		1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3	0.450	1		Road
Motale	Sawn Hardwood Sawn Softwood Sub-total	sheet	1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3 Unit Conversion or Density 8.9 tonnes/m3	0.400 0.031 0.240 0.200 tCO <sub>2</sub> e/t or unit	Tonnage or unit	Distance	Mode
Metals	Sawn Hardwood Sawn Softwood Sub-total	Sheet	1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3 Unit Conversion or Density 8.9 tonnes/m3 8.9 tonnes/m3	0.430 0.031 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.77 0.27	Tonnage or unit	Distance	Mode
Metals	Sawn Hardwood Sawn Softwood Sub-total Copper: EU Tube & S Copper: Reused cop Iron Irean	Sheet per	1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3 Unit Conversion or Density 8.9 tonnes/m3 8.9 tonnes/m3 7.87 tonnes/m3 1.4 tonnes/m3	0.430 0.031 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.71 0.27 2.03	Tonnage or unit	Distance	Mode
Metals	Sawn Hardwood Sawn Softwood Sub-total Copper: EU Tube & S Copper: Reused cop Iron Leaa Steel: General - UK (	Sheet per EU) Average	1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3 Unit Conversion or Density 8.9 tonnes/m3 7.87 tonnes/m3 11.34 tonnes/m3	0.430 0.031 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.77 0.27 2.03 1.87	Tonnage or unit	Distance	Mode
Metals	Sawn Softwood Sub-total Copper: EU 1056 & 3 Copper: Reused cop Iron Lead Steel: General - UK ( Recycled Content Steel: Bar Kod - UK	Sheet per EU) Average (EU) Average	1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 7.87 tonnes/m3 11.34 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3	0.435 0.03 0.24( 0.200 tCO <sub>2</sub> e/t or unit 2./1 0.27 2.03 1.8/ 1.8/	Tonnage or unit	Distance	Mode
Metals	Sawn Hardwood Sawn Softwood Sub-total Copper: EU 1006 3: Copper: Reused cop Iron Lead Steel: General - UK ( Recycled Content Steel: Sar Kord - UK Recycled Content Steel: Sar Kord - UK	Sheet per EU) Average (EU) Average ialvanised - UK	1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 <b>Unit Conversion</b> or Density 8.9 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3	0.445 0.031 0.240 0.200 tCO_e/t or unit 2.71 0.27 0.27 0.27 0.27 1.57 1.46 1.40	Tonnage or unit	Distance	Mode
Metals	Sawn Hardwood Sawn Softwood Sub-total Copper: EU 1086 & 3 Copper: Reused cop Iron Leale Steal: General - UK Recycled Content Recycled Content Recycled Content Steal: Gheeti, G (EU) Average Recycl	Sheet per (EU) Average (EU) Average alvanised - UK ed Content	1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 8.9 tonnes/m3 11.34 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3	0.440, 0.031 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.77 0.27 2.03 1.66 1.46 1.46 1.54	Tonnage or unit	Distance	Road Mode Road
Metais	Sawn Hardwood Sawn Softwood Sub-total Copper: Reused cop Iron Lead Steel: General – UK Steel: General – UK Steel: General – UK Steel: Content Steel: Engineering st	Sheet per EU) Average (EU) Average advanised - UK ed Content eel - Recycled	1 tonnes/m3 0.6 tonnes/m3 0.5 tonnes/m3 Unit Conversion or Density 8 y tonnes/m3 7.8 y tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3	0.440, 0.031 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.77 0.27 2.03 1.66 1.46 1.56 0.77	Tonnage or unit	Distance 661	Road Mode Road
Metals	Sawn Hardwood Sawn Softwood Sub-total Copper: Reused cop Iron Recycled Content Steel: General – UK Steel: General – UK Steel: General – UK Steel: Engineering st Steel: Engineering st Steel: Engineering st Steel: Engineering st	Sheet per EU) Average (EU) Average alvanised - UK ed Content eel - Recycled Average Recycled	1 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 8.9 tonnes/m3 7.87 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3 7.8 tonnes/m3	0.440 0.033 0.244 0.200 tCO <sub>2</sub> e/t or unit 2.75 0.27 2.03 1.46 1.46 0.77 1.46	Tonnage or unit	Distance	Road Mode Road
Metais	Sawn Hardwood Sawn Softwood Sub-total Copper: Reused cop Too Too Steel: General – UK ( Recycled Content ( Eu) Average Recycl Steel: Engineering at Steel: Engineering at Steel: Engineering at Steel: Engineering at Steel: Engineering at Steel: Engineering at	Sheet per EU) Average (EU) Average alavanised - UK eel - Recycled Average Recycle	1 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 7.8 tonnes/m3	0.440, 0.033 0.24( 0.20( tCO <sub>2</sub> e/t or unit 2.73 0.27 2.03 1.67 1.46 1.54 0.77 1.45 1.65	Tonnage or unit	Distance	Road Mode Road
Metais	Sawn Hardwood Sawn Softwood Sub-total Copper: Reused cop Tron Lead Steel: Ceneral - UK (Recycled Content Steel: Seneral - UK (Recycled Content Steel: Seneral - UK (EU) Content Steel: Pipe-UK (EU) Content Steel: Pipe-UK (EU) Content Steel: Content Steel: Content Steel: Content	SReet per EU) Average (EU) Average alavanised – UK eel - Recycled Average Recycle I Average (EU) Average	1 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 1.3 tonnes/m3 7.8 tonnes/m3	0.445 0.033 0.24( 0.200 tCO_set or unit 2.77 0.27 2.03 1.66 1.55 1.	Tonnage or unit	0istance	Road Mode Road
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Metais	Sawn Hardwood Sawn Softwood Sub-total Copper: EU 1086 3: Copper: Reused cop Trion Lead Steel: General - UK Recycled Content Steel: Sael X and - UK Recycled Content Steel: Cael X and - UK Recycled Content Steel: Steel: Cael (Sheet), C Steel: Park and - UK Recycled Content Steel: Steel: Ste	SReet per (EU) Average (EU) Average islavnised - UK led Content Haverage Recycled Average Recycled (EU) Average	1 tonnes/m3 0.6 tonnes/m3 0.6 tonnes/m3 0.6 tonnes/m3 0.6 tonnes/m3 0.7 tonnes/m3 7.8 tonnes/m3	0.440 0.033 0.240 0.200 tCO <sub>2</sub> o/t or unit 2.77 0.27 2.03 1.56 1.46 1.55 1	0	0istance	Road Mode Road
Motais	Sawn Hardwood Sawn Softwood Sub-total Copper: EU 1066 & 1 Copper: Reused cop Tron Lead Steel: General - UK Recycled Content Steel: Saw Tod - UK Recycled Content Steel: Fagineering & Steel: Fagineering & Steel: Fagineering & Steel: Fagineering & Steel: Fagineering & Steel: Steel: Fagineering & Steel: Steel: Fagineering & Steel: Steel: St	Steet per EU) Average (EU) Average d'avarage Average el - Recycled Average Recycle I Average	1 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 0.5 tonnes/m3 8.9 tonnes/m3 7.8 tonnes/m3	0.445 0.03 0.240 0.240 0.200 tCO <sub>2</sub> e/t or unit 2.77 0.27 0.27 0.27 0.27 1.57 1.56 1.66 1.55 1.55 1.55 0.652 0.16 9.645 0.52	0	0istance	Road Mode Road
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Plastics	Plastics: general	1.38 tonnes/m3	3.31		
	Polyethylene: general	0.92 tonnes/m3	2.54		
	High Density Polyethylene (HDPE) Resin	0.96 tonnes/m3	1.93		
	HDPE Pipe	1.05 tonnes/m3	2.52		
	Expanded Polystyrene	1.05 tonnes/m3	3.29		
	General Purpose Polystyrene	1.05 tonnes/m3	3.43		
	High Impact Polystyrene	1.05 tonnes/m3	3.42		



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Footprint (tonnes fossil CO <sub>2</sub> e)					
Embodied	Transport	Sum			
0.2	0.0	0.2			
0.118	0.002	0.120			
0.156	0.001	0.157			
0.150	0.001	0.157			
1.0	0.0	1.0			

0.041	0.002	0.039		
0.0	0.0	0.0		

Title of project: Construction cost:		1						
Total Carbon Footprint:	1.8	tonnes foss	II CO28					
	We would like to hear from you				The state			
We would like to build a databas ideas and lessons learnt.	e of case studies on the EA website to	share knowled	ge, emission reduction			nmei	1L	
Please send your completed ex	amples tocc@environment-agency.gov	uk Do not forg	et to include a short					
Preject Information page.	ures you have identified for the reduction	on of the total o	arbon lootprint in the		Agency	7		
Personnel travel		1						
H					© Environment Agency copyright and/or database right 2007			
Material transport	0				All rights reserved			
H								
Portable site	0				Sub-totals	tonnes CO <sub>2</sub> e	%	
					Quarried Material	0.2	8% 40%	
Waste Removal	0				Concrete, Mortars & Cement	0.0	0%	
					Plastics	0.0	2%	
Plant and equipment emissions	0				Glass Miscellaneous	0.0	0% 6%	
Einichinge coatinge &					Finishings, coatings & adhesives	0.0	0%	
adhesives	4					0.0	U%	
1					Portable site accommodation	0.4	16% 0%	
Miscellaneous	0				Material transport Personnel travel	0.0 0.6	0% 26%	
A							*	
Glass	0							
Η								
Plastics	U				Significant materials (figures include transport to site)			
Motale	0							
Metals	U							
Concrete, Mortars &	0							
Cement								
Timber			1					
Quarried Material	0		,					
	• - •	-						
	Tonnes CO <sub>2</sub>	e						
					Site accommodation - Grid electricity	0.012	tonnes CO2e	
_								
<ul> <li>The accuracy of individual value factors and estimated tonnages</li> </ul>	s is unlikely to be better than +/-5%. A carbon footprints obtained from this c	s a consequen alculator might	ce of using default be expected to be with					
+/-25% of the true value. Given default values may give results	the range of values associated with ce that are out by 100% or more. Local d	ertain materials ata should be t	cements for example	»),	rockwool insulation	0.138	tonnes CO2e	
					polipropylene	0.050	tonnes CO2e	
		1						
				-				
		1						
				-				
				-				
				-				
<u> </u>								
						1		

#### **Final Assignment Submission Declaration**

Essay Title: Monitoring Plan: Sustainable Retrofit Plan. Pre-1919 Mid of Terrace House.

Module: Low Carbon Buildings

Before submitting your essay, please complete the following checklist, fill in the number of words in your assignment, and then sign the declaration at the bottom of the page:

#### Checklist:

- ✓ □ I have taken into account guidance provided by the assignment brief and by the module tutor.
- ✓ □ I have acknowledged and documented all sources from which I have borrowed ideas and information
- I have ensured that any computer software used in the preparation of this work is appropriately licensed.
- $\checkmark$   $\Box$  I have proofread my essay.
- ✓ □ I have used a font of at least Arial 11 and left a reasonable margin space around the work.
- ✓ □ Number of words: 2700 not including the abstract, contents list, tables, figures, reference list

#### **Declaration:**

This assignment is my own work, and does not involve either plagiarism or collusion

Plagiarism: is defined as "using words or ideas of others	Collusion: is said to occur when "work has
without acknowledging them as such and submitting	been undertaken by or with others is
them for assessment as though they were one's own	submitted and passed off as solely the work
work" (para 2.1.1, University Academic Regulations	of one person" (para 2.1.2, University
Handbook). This includes direct copying, close	Academic Regulations Handbook).
paraphrase, the unacknowledged use of ideas developed	Where this is done with the knowledge of the
by others and commercial essay bank services.	originator, both parties can be considered to
	be at fault.

The text of my assignment submission (not including title and reference list) is not more than 2750 words.

Student id: 1948781 Course: ENVIRONMENTAL DESIGN OF BUILDINGS 2DL

Date:1 03/04/2020

✓ I confirm by ticking this box that the information given in this form is correct.