Retrofit and Carbon Reduction Cost Analysis of a Circa 1930 UK Dwelling

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***Abstract*—Reduction in energy consumption and carbon emissions associated with a low-energy retrofit of a hypothetical case-study semi-detached British house in compliance with UK Energy Saving Trust and the UK Code for Sustainable Homes (L.3) requirements are investigated using retrofit options and cost data from real-life projects. Retrofit capital cost is contrasted with energy cost savings. It is shown that retrofit cost can achieve acceptable payback so long as selection of low-carbon materials is reconciled with the homeowners' budget because both have considerable cost implications.**

Keywords—Low-carbon retrofit, embodied CO_2, housing stock, energy consumption

I INTRODUCTION

The UK Climate Change Act (HMGoverment, 2008) underpins the UK response to climate change. Its target is reduced UK carbon dioxide (CO_2) emissions ['emissions' hereafter for brevity] of ≥80% by 2050 using 1990 baseline levels. UK domestic buildings are responsible for major emissions both during construction and habitation (Power, 2008). Domestic energy use accounts for 27% of these (Kelly, 2009); approximately 16% emanate from housing that uses fossil fuel for heating and cooking; and 40% comes from the domestic electricity supply sector (DECC, 2014).

More than 20 million UK dwellings (75% total stock) were built post-1900. Given subsequent technical innovations and more stringent regulations, these have poor contemporary energy performance standards. Eighty-seven per cent of these are expected to remain habitable until 2050 (Gupta and Chandiwala, 2010) if present demolition rates remain unchanged (Fawcett and Boardman, 2009). In England >70% of post-1900 dwellings are in poor repair with inadequate thermal insulation (Thorpe, 2010). Thus, the 80% CO_2 reduction above suggests that their low- and zero-carbon energy-efficient refurbishment will be required, to help achieve this. About £200GBP ($321USD) billion investment is needed to make any significant impact (LCC, 2010).

Embodied CO_2 constitutes 28% of the total emitted over an estimated first 50 years' lifetime of new properties; in contrast to 10% over the lifetime of similar, renovated properties (HEHA, 2008): compelling evidence to support retrofitting of existing stock and implying that embodied energy and emissions savings provide great opportunity for contributing to energy and CO_2 targets alluded to at the outset. Successful low-carbon retrofit (LCR) first requires homeowners to make informed choices, on how best to invest in technical solutions. This study focuses on the cost-saving potential of such investment because arguably, this is the most important criterion upon which the decision is made. It also focuses on reduction of housing stock emissions; an ambition presently shared between low-impact new building designs and improvement of performance in existing ones. Specifically, LCRting requires evaluation of: its costs; benefits related to energy use; CO_2 reduction; low-carbon materials; and building performance. This study analyses these through a hypothetical case-study that assumes a post-1930s three-bedroom semi-detached dwelling. A hypothetical case-study is appropriate because it was designed to encompass all relevant features of this kind of building and is typical of existing poor energy-efficient UK housing stock. The emphasis is heat loss minimisation via low- or zero-carbon insulation of building fabric in the most cost-effective way.

Empirical study comprised two stages. Stage 1 cost appraised the benefits of a LCR, based on strategic carbon performance improvement of building fabric, including reduced air leakage and achievement of U-values in accordance with the UK Code for Sustainable Homes Level 3 recommendations. Resulting energy savings were compared to a similar property where no retrofitting had taken place. An elemental cost analysis was based on key fabric components (ground floor, cavity wall and internal wall insulation; windows and doors replacement; loft insulation). In Stage 2, embodied energy and CO_2 were calculated based on the low-carbon materials used, and costed using data from real-life retrofit projects.

II CURRENT RESEARCH: LCR

The two primary propositions among the literature in relation to this study are: existing stock management including the option of demolition; and improvement in energy supply, transmission, distribution and end-use systems of existing dwellings. See for example: Kelly (2009); Lomas (2009); Lowe (2007); Moss (2006); Power (2008); Thomsen *et al.* (2011); Boardman (2012); Thomsen and Van Der Flier (2009). Demolition has sparked much debate due to issues of heritage preservation and wider social consequences; while the latter proposition emphasises efficiency and reduced energy consumption.

Nationally, improvements in energy use are continually offset by population growth and increased demand due to modern lifestyles. Jones *et al.* (2013) confirmed significant reduction in emissions and a positive impact on living comfort from retrofit case studies but the payback cost of a 'whole-house' retrofit was unrealistic. The Energy Saving Trust (EST) showed that very few 'whole-house' case studies exceeded best practice standards (EST, 2007); stating that sufficient resources and technical advice are required to achieve this. It was also found that homeowners' attempts at 'whole-house' retrofit is often performed in stages (i.e. one aspect of building fabric at a time).

Since 1970, UK domestic energy use has increased by one-quarter and current consumption is c.26% of all UK energy (Palmer and Coope, 2012). The Digest of UK Energy Statistics estimated an average £105.3m was spent annually on UK energy and attributed 24% of this to domestic users (DECC, 2013a). Gas and electricity average expenditure per household (2001-12) have increased by 62% and 31% respectively (DECC, 2013b; 2013c). This has a particular impact on low-income homeowners, who may find it much harder to afford energy efficiency improvements. Poor energy efficiency is one of the main causes of fuel poverty (DECC, 2013d). The Office for National Statistics (ONS, 2011), confirm that lower-income households spend more on energy than higher-income homeowners so cost-effective energy-efficient solutions for existing houses have potential to help eradicate fuel poverty.

Housing also contributes significantly to UK emissions (Palmer and Coope, 2012). Department of Energy and Climate Change (DECC) annual data show that since 2009, around 40% of total UK emissions, is caused by generating energy (DECC, 2013a). Domestic fuel consumption generates considerable emissions; an inefficient building requires significant heating to compensate for its heat loss. Space heating and water heating combined, accounted for more than 79% of this consumption in 2009, followed by appliances (13%), lighting (3%), and cooking (3%). Of all UK household energy use, space heating has increased by nearly a quarter since 1970 (Palmer and Coope, 2012). Total energy use has increased also due to growth in number of new homes (41% post-1970) and demand for warmer homes (Palmer and Coope, 2012); so housing offers a major opportunity to cut energy usage and emissions. In this study, thermal insulation of an existing building is taken as one of the most cost-effective solutions to achieve this.

There are approximately 26m houses in the UK (Utley and Shorrock, 2012), 88% of which are in England and 79% of these were built after 1919 of which 26% are semi-detached (HMGoverment, 2012). This includes 'hard-to-treat' houses (solid wall dwellings without gas heating) with poor energy performance needing substantial refurbishment and whose energy use and emissions are considerably higher than new buildings (EST, 2010a). Debate over demolition of poor housing has intensified (Boardman *et al.*, 2005; SDC, 2005; Lowe, 2007). Large-scale demolition has been proposed to make way for energy-efficient buildings (Power, 2008) and comply with tighter regulations. According to Boardman (2007), the annual demolition rate is less than 0.1% of existing stock, while average annual new builds since 2007 are 0.6% of existing stock (HMGoverment, 2013a).

Post-2006 reduction in construction activities (ONS, 2013) has resulted in a shortage of new houses and impacted the supply of sustainable, energy-efficient ones. This implies that the demolition route to achieving cuts in emissions is contentious, because slow replacement with new will never achieve targets, unless complemented with large-scale, LCR of existing stock. It is therefore vital to understand any performance gap between actual energy and emission reductions against predicted targets; estimate retrofit costs and anticipated cost savings from energy use; predict the level of living comfort that will result; assess the availability of technical options; and potential effects of relevant legislation.

Estimates suggest £200 billion investment is required by 2050 to achieve a 60% reduction in emissions, an average of £7,500 per dwelling or £5 billion p.a. to achieve 2050 CO_2 reduction targets (LCC, 2010). The scale of LCR can vary for each dwelling depending on (inter-alia) types of fabric components, geographic location, property condition, energy supply and heating systems, post-retrofit performance requirements, and affordability – factors also having significant impact on LCR cost. Uptake in energy-efficient retrofit is presently low, but a variety of funding packages are available for homeowners as encouragement, one of which is the 'Green Deal' (GD). GD eliminates the up-front cost of LCR for businesses and homeowners, by linking repayments to energy savings and spreading them over many years. GD requires the anticipated financial saving to be ≥ the cost attached to the energy bill during the repayment period. Guertler (2012) found that GD can positively impact on energy saving. The UK Green Building Council (GBC) reported that more than 38,000 assessments were carried out in the first six months of the GD since its launch in January 2013 (GBC, 2013a), but due to delays in finance being made available, only 245 GD plans had been agreed. A separate report (GBC, 2013b) commented that the GD needed to improve in order to deliver at the required rate and highlighted poor levels of understanding about the scheme among stakeholders. It is vital to accelerate uptake, if a large-scale retrofit programme is to be effectively rolled out.

Within the UK, more than four million semi-detached houses were built during the inter world-war period; representing >30% of existing stock (Cook, 2009). This type of property was very popular throughout 1930-45; so a significant proportion of UK dwellings are of this design (Jensen, 2007). According to the English Housing Survey report, around 80% of English dwellings built after 1919 still exist; and 26% of these are semi-detached (HMGoverment, 2013a). They were originally constructed without any wall insulation. Ground floors were either of raised timber or, in-situ concrete slab – both without insulation. Their roof space was typically un-insulated and the windows were single-glazed (Thorpe, 2010). For this research, a typical three-bedroom post-1930 property constructed as described in this manner is assumed as the basis for calculating the carbon cost, for its retrospective refurbishment and to derive energy savings and environmental benefits thereafter.

III RESEARCH METHODOLOGY

LCR cost data were obtained from contractors through interviews and site visits, of 10 typical 1930s semi-detached three-bedroom houses undergoing 'whole-house' retrofits. These data provided average gross internal floor area (GIFA) and quantities for external walls, ceiling and windows of the case-study dwelling. Mean results were: GIFA = 97m^2 (51m^2 ground floor, 46m^2 upper floor); 51m^2 of 50mm thick loft insulation; 116m^2 of un-insulated cavity wall; 21m^2 of singled glazed windows; and two un-insulated external solid doors. Retrofitting costs were based on cost measurements for the 'whole-house', calculated using an elemental approach based on individual fabrics: insulation for ground floor and external walls; door and window replacements; and loft insulation. This yielded a breakdown cost, thereby facilitating detailed information for comparison with anticipated fuel savings and other benefits. To calculate heat escape through building fabric pre- and post-retrofit, a steady-state heat loss formula was used (Chadderton, 2013):

$$Q_u = \sum(AU)(t_{ei} - t_{ao})W \quad \text{(Eq. 1)}$$

Where: Q_u represents the steady-state heat loss; $\Sigma(AU)$ = the sum of the area and thermal transmittance (U-value) of the external wall; t_{ei} = average internal air temperature; t_{ao} = average outside air temperature; and W = watts (Chadderton, 2013). To quantify heat loss through a composite building fabric (e.g. a cavity wall) its thermal transmittance (U-value) is required – being a function of the thermal resistances (R) of its constituent parts. A material's resistance to heat flow depends on its thickness, density, water content and temperature. The thermal transmittance value is calculated from the reciprocal of the sum of the resistances of each layer or adjacent materials. For instance, heat transmission across a cavity depends upon its width, whether or not it is ventilated and its surface emissivity (Moss, 2006). For brevity and to focus on the study's main aims, energy savings were calculated from the net heat loss. That is, the difference between total heat loss before and after retrofit; based on thermal properties of the insulation materials used (EST, 2010a).

IV ANALYSIS

A. *Performance Pre-retrofit*

The hypothetical case-study dwelling is assumed owner occupied. It has one dividing wall (with the adjacent property) and is almost 80 years old with a potential lifespan of at least another 40 years. This un-insulated property is rated Band E in terms of its Energy Performance Certificate (EPC) and produces 6.5 tonnes of carbon annually (EST, 2010a).

B. *Existing and Target Fabric U-values*

EST and Code 3 recommend 'whole-house' insulation and sufficient airtight measures respectively, to prevent heat loss through dwelling fabric and minimise ventilation heat loss. For instance, case-study cavity walls were insulated with expanded polystyrene beads and internal thermal board to achieve the EST recommended U-value. **Table 1** summarises fabric U-values, before and after retrofitting. Pre-retrofit U-values were calculated using the Reduced Data Standard Assessment Procedure (RdSAP 2009 version 9.91 Appendix S)[1] . The post-retrofit U-values were estimated based on CISBE Guide A (CIBSE, 2006) and EST insulation materials chart (EST, 2010b).

C. *Cost of Retrofitting*

The sample interviews determined average thermal upgrade costs per m^2 and include for 20% preliminaries and 10% profit. The average cost per m^2 for each element (floor, wall, door and window, and roof) was benchmarked against Building Cost Information Service data and no significant differences were found.

D. *Ground floor insulation*

The type of existing ground floor and its condition determine how best to improve its thermal capabilities – most common methods are to insulate a suspended

[1] UK government official procedure for use in existing dwellings when SAP is not possible.

timber ground floor between the joists, or, replace it with a concrete floor incorporating semi-rigid sheet insulation. The former costs less, but the solid floor option provides better insulation and endurance (EST, 2010a). The case-study assumed: remove existing 100mm concrete slab floor; excavate a further 200mm below this; add 100mm hardcore, sand blinding and DPM; 120mm rigid insulation, 30mm thermal board and sand/ cement screed. Including removal of spoil from site, unit cost was £138/m^2 or for a 51m ^{2} floor area, a total cost of £7,038.

TABLE 1: BUILDING FABRIC U-VALUES BEFORE AND AFTER A RETROFIT

Building component	U-value (W/m²K)			
	Before retrofit	After retrofit	EST Best Practice	CSH Level 3 (Part L 1A)
Solid floor	0.70[a]	0.20[f]	0.20-0.25	0.25
Cavity wall (50mm cav)	1.6[b]	0.399	0.50-0.60	0.35
Window	4.8[c]	1.60[h]	1.60	EPC or 2.00
Solid door	3.0 [d]	1.00[i]	1.00	2.20
Pitched roof	0.68[e]	0.15[j]	0.15	0.25

[a] RdSAP S5.4 U-values of solid floor next to ground. [b] RdSAP S5.1 U-values of cavity walls, Table S6 Cavity as built – Age Bands C, D and E (post-1930 dwellings). [c] RdSAP S8.2 Window U-values Table S14 Single-glazed. [d] RdSAP S8.3 Door U-values, Table S15A Age Bands A-J. [e] RdSAP S5.3 U-values of roof, Table S9 50mm thick insulation between ceiling joists. [f] EST (2010a)/ manufacturer data 120mm rigid insulation. *[g] CIBSE Guide A (CIBSE, 2006, McMullan, 2007) environmental design guide – based on 50mm expanded polystyrene beads and 30mm thermal board. [h] EST (EST, 2007, 2010a) EPC Band C and PVCu window manufacturers' publications. [i] EST (EST, 2007, 2010a) and PVCu door manufacturers. [j] EST (EST, 2010a) loft insulation.*

E. Cavity wall insulation

Most post-1930 semi-detached houses are masonry cavity (50-100mm) wall construction (EST, 2010a). Installing cavity insulation in these can reduce heat loss by up to 60% (EST, 2007). In this study a 50mm cavity was assumed. Thermal improvement was achieved by injecting polyurethane insulation into this cavity and by fixing a 30mm thermal board to the internal face of the wall, finished with 3mm plaster skim. Cost was £69.09/m^2 which for a wall area of 116m^2 gave a total cost of £8,014.

F. Windows and external doors

Heat loss through single-glazed window is about 3-4 times that of double glazing (Cook, 2009). High performance glazing also reduces infiltration losses. An un-insulated (e.g. solid timber) external door contributes around 15% of total fabric heat loss; by upgrading this to a un-plasticised Poly Vinyl Chloride (PVCu) insulated door, 60% heat loss reduction can be achieved (EST, 2010a). Costs were 21m^2 of windows at £2,580 plus two doors at £948 = £3,528 total.

G. Loft insulation

This is one of the most cost efficient and effective methods to improve thermal performance. Pitched roofs should be insulated at ceiling level or at roof level at the rafters, to a maximum U-value of 0.16W/m2K and draught sealing must apply to any service penetrations. Insulation upgrades must also take account of maintaining ventilation and/ or insertion of vapour barriers, to negate risks of interstitial condensation. The study assumed a layer of 100mm thick mineral wool insulation between ceiling joists and a subsequent layer of 200mm thick insulation laid in a transverse direction above this. At £6.27m^2 this equates to a total cost of £320.

H. Heat loss

Heat loss is exacerbated by the existence of gaps in the building envelope (intentionally such as through an open window light or unintentionally such as where services pass through the structure). Collectively, this is referred to as 'ventilation heat loss'. In order to calculate the total loss, room temperature was maintained at an average of 21^{o}C throughout the year. The average outdoor temperature was obtained from the Meteorological Office online database (MetOffice, 2010) and for the South England region, this was 10.05^{o}C. Using the steady-state heat loss formula in Equation 1, **Table 2** shows the calculations of hourly and annual heat loss through the building fabric pre- and post-retrofit. Net hourly heat loss is 2.9kWh or 25,687kW p.a. through the entire building fabric. To compensate for this, the same amount of energy is required to maintain the internal temperature at average 21^{o}C (**Table 3**).

TABLE 2: HOURLY HEAT LOSS POST-RETROFIT

Building fabric	Area (m²)	U-values diff[a]	Annual temp. diff[b]	Hourly heat loss[c]	Annual heat loss[d]
Solid floor	51	0.50	10.95	279	2,447
Cavity wall	116	1.21	10.95	1,538	13,469
Window	21	3.20	10.95	736	6,448
Solid door	3.8	2.00	10.95	83	729
Pitched roof	51	0.53	10.95	296	2,594
			Totals	2,932	25,687

[a]After/ before retrofit – Table 1. [b]Degrees centigrade (indoor/outdoor). [c]Through building fabric (W)[c] from = (area) x (U-value) x (difference between internal/external temperature ^{o}C). [d]Via building fabric (kW)

TABLE 3: ANNUAL ENERGY SAVINGS FOR BUILDING FABRIC

Building fabric	Annual savings				
	Energy use due to heat loss (kW/hr)	Annual energy use due to heat loss (kW)	Energy cost @ (£4.64p/ kWh)[a]	Cost inc. 26.25p daily standing charge[b]	Energy saving (%)
Solid floor	0.2793	2,447	114	209	13
Cavity wall (50mm)	1.5375	13,469	625	721	43
Window	0.7361	6,448	299	395	24
Solid door	0.0833	729	34	130	8
Pitched roof	0.2961	2,594	120	216	13
Totals	2.93	25,687	1,192	1,671	100%

[a]Average price on a typical three-bedroom house heated by gas with average boiler efficiency of 80% (www.est.org.uk). [b]Typical standing charge gas tariff from the UK major energy suppliers.

V DISCUSSION

The analysis identified that cavity wall insulation contributes 43% of total energy cost-saving compared to other fabric improvements (Table 3); but represents the most expensive improvement (42%) (**Table 4**). In contrast, loft insulation cost least (2%) but makes the significant contribution to energy cost reduction (13%, Table 3). Every 1% of loft insulation cost produces around 40 times percentage saving in energy bills.

TABLE 4: PRE/ POST-RETROFIT ANNUAL SAVINGS PER FABRIC

Building fabric	Annual energy use (kW)		Cost and saving		
	Before retrofit	*After retrofit*	*Post-retrofit saving (%)*	*Retrofit cost (£)*	*Retrofit cost (%)*
Solid floor	3,426	979	71	7,038	37%
Cavity wall (50mm)	17,810	4,341	76	8,014	42%
Window	9,673	3,224	67	2,580	14%
Solid door	1,094	365	67	948	5%
Pitched roof	3,328	734	78	320	2%
Totals	35,330	9,643	73	18,900	100%

Given that proportions of total domestic heat loss from walls (35%), roofs (25%), floors (15%), windows (10%) and doors (15%) are inconsistent, strategic decision-making in improving energy efficiency is of vital importance. Wall and loft insulation represent the most cost-effective solutions to achieve this. In terms of a 'whole-house' retrofit, the total estimated yearly saving is 25,687kW – a 73% saving on energy consumption before retrofit (Table 4).

In this study, total annual savings took into account a 7.76% inflationary increase in fuel prices but nonetheless; a payback period analysis showed a break-even point on the investment in year eight at present prices. Taking account of the time value of money, subsequent comparisons or calculations of capital costs would for instance, need to consider inflationary impacts. Further, the present calculation does not include interest foregone on capital invested in the retrofit, or, interest accrued on borrowed capital. These are factors that can negatively affect payback calculations and extend the break-even period.

To assess the environmental impacts of the case-study, a life cycle methodology determined embodied energy and CO2. Based on data in Appendix A, the total embodied energy and CO2 are 176,073.36 MJ and 9,372.16 Kg CO2 respectively. Given that the habitable floor area of the dwelling is 97m^2, embodied energy and CO2 converted to m^2 units becomes 1.82 GJ/m^2 and 96.62 KgCO2/m^2 respectively. Data for embodied energy and CO2 for houses are scarce and where they do exist, exhibit variance; caused by differences in computational methods, lack of clarity of the constituent building material types, and discrepancies in database inventories. Despite this, results of this study are compared to those of others.

Pullen (2000) reported embodied energy of 3.6GJ/m^2 for a residential building. Hammond and Jones (2008) reported a mean of 5.3GJ/m^2 and 403KgCO2/m^2 embodied energy and CO2 respectively from 14 residential case studies, while Dixit *et al.* (2010) found a mean of 5.5GJ/m^2 embodied energy for residential buildings. The results of 1.82GJ/m^2 and 96.62KgCO2/m^2 for embodied energy and CO_2 in this study cannot be *broadly* generalised, but the results are nonetheless robust and compared to those studies cited above, suggest much lower CO_2 values. The (four times) greater amount of CO_2 associated with new build (*vis-à-vis* refurbishment) is in line with HEHA (2008).

New homes emit on average 0.86 tonnes operational CO_2 p.a. while existing homes emit 1.6 tonnes (CLGC, 2008). Tuominen *et al.* (2012) reveal that through energy efficiency measures, about 70,000 GWh/annum energy reduction and 20,000 GWh/annum cost savings can be made from current UK housing stock – representing approximately 20% energy reduction and 30% cost savings relative to present consumption.

Furthermore, there is a potential that operational carbon will significantly reduce in new homes, requiring that more attention needs to be paid on embodied energy. In the UK, Sturgis and Roberts (2010) predicted the proportion of embodied carbon to increase from 30% to 95% while operational will reduce to 5% from 70% over the coming decade years from stricter legislation. This implies that new buildings with 'nearly zero energy' and energy efficiency retrofit of existing house stock can offer significant savings for the future.

This study provides evidence to support refurbishment of existing stock in preference to demolition or replacement with new build. In addition to cost, embodied energy and CO_2 savings highlighted here, other benefits include improved comfort levels and increased property values as a result of improved energy efficiency ratings. Retrofit preserves the vernacular and aesthetics of period houses, while minimising disruption and offers advantages from a social perspective. Hence, LCR brings economic, environmental and social benefits to the dwelling owner, the occupier, and society at large.

The costs and benefits analysis in this study considered a 'whole-house' fabric retrofit; for which it is vital to identify the most cost-effective elemental combinations of fabric to achieve maximum savings. Savings and predicted payback accuracy could be improved by considering energy use before and after the retrofit over a reasonable period of observation. This would require details of the dwellings' location, orientation, day lighting and electric lighting, airflow, ventilation, climate, heat losses/gains through inhabitant activities, and thermal performance characteristics of internal building materials. Such is fundamental for accurate carbon calculations and so signposts future research in this field.

VI Conclusions

Large-scale demolition of older dwellings has been proposed for them to be replaced with energy-efficient new ones. However, current rates of demolition and new build figures suggest that the replacement of older houses in this way, will not achieve the CO_2 reduction target for existing housing stock explicit within the UK Climate Change Act 2008. Retrofitting and renovation is potentially more financially attractive and effective, to achieving these reductions.

LCR of older dwellings therefore, has a significant role to play – indeed, the 80% reduction in emissions by 2050 may not be achievable without such. This study has demonstrated the benefits of this kind of property upgrade, for which owners can benefit from better choices regarding LCR; based on their 'affordability' – and the benefits of performing this kind of upgrade (financial and environmental as demonstrated here) need to be more clearly communicated to them, in order to encourage take-up.

Findings provide an exemplar case-study of how a 1930s property can achieve significant savings for a 'whole-house' insulation upgrade, in line with EST Best Practice. Although savings from energy bills represent an investment payback period to meet a break-even point, refurbishment also gives some protection against further or sharp rises in future fuel prices; improved comfort in their homes; improved resistance to (possibly more frequent) extreme weather in future years; and improved property market value.

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APPENDIX A: RETROFIT EMBODIED ENERGY AND CO_2 OF A THREE-BEDROOM SEMI-DETACHED 1930 DWELLING

	Unit	Volumn based on 51m2 of GIFA	Density (Kg/m3)	Qty(Kg)	Embodied Energy Intensity (MJ/Kg)	Embodied Carbon Intensity (KgCO2/Kg)	Embodied Energy (MJ)	Embodied carbon (KgCO2)
GROUND FLOOR								
100mm hardcore base on substrate (gravel and crushed rock)	m3	5.1000	2240	11424	0.083	0.0048	948.192	54.8352
25mm sand blinding	m3	1.2750	2240	2856	0.081	0.0048	231.336	13.7088
100mm concrete slab (300Kg/m3 concrete)	m3	5.1000	2500	12750	0.91	0.131	11602.5	1670.25
120mm Kingspan Thermal floor TF70 rigid insulation board	m3	6.1200	160	979.2	45	1.86	44064	1821.312
Sand & cement screed 30mm	m3	1.5300	1900	2907	0.85	0.127	2470.95	369.189
	Sub-total						***59,316.98***	***3,929.30***
ROOF INSULATION								
270mm mineral wool insulation	m3	5.1000	140	714	16.6	1.2	11852.4	856.8
	Sub-total						***11,852.40***	***856.80***
CAVITY WALL								
Expanded polyurethane injection beads	m3	6.9600	24	167.04	102.1	4.06	17054.784	678.1824
30mm Gyproc ThermaLine BASIC thermal board	m3	3.4800	950	3306	6.75	0.38	22315.5	1256.28
3mm plaster skim	m3	0.3480	1200	417.6	1.8	0.12	751.68	50.112
	Sub-total						***40,121.96***	***1,984.57***
WINDOW AND DOOR								
Door: panel (35% double glazed)	m3	0.0103	25	0.25704	15	0.86	3.8556	0.2210544
Door: panel (65% uPVC)	m3	0.1596	1380	220.18424	77.2	2.61	16998.22364	574.680877
Door: panel (3% Aluminium)	m3	0.0163	2700	44.118	155	8.24	6838.29	363.53232
Door frame (95% UPVC cover on steel plates)	m3	0.0558	1380	77.068446	77.2	2.61	5949.684031	201.148644
Door frame (5% steel plates)	m3	0.0018	7800	14.10864	20.1	1.37	283.583664	19.3288368
Window panel (90% double glazed)	m3	0.1599	25	3.99672	15	0.86	59.9508	3.4371792
Windows frame (10% uPVC)	m3	0.1913	1380	263.95481	77.2	2.61	20377.31118	688.922049
Window: frame (Steel plate)	m3	0.0084	7800	65.46384	218	11.46	14271.11712	750.215606
	Sub-total						***64,782.02***	***2,601.49***
Grand-total							**176,073.36**	**9,372.16**