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A Community-based Whole Life Carbon Assessment: Case study of a London estate community plan

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A Community-based Whole Life Carbon Assessment: Case study of a London estate community plan

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Abstract. In the attempt to adhere to the UK's 2050 Net-Zero Strategy, more attention has been given to energy-centric decision-making over the regeneration of housing estates. Whole Life Carbon Assessment (WLCA) is the methodology used for the evaluation of the overall carbon dioxide equivalent (CO2e) emissions of building projects over their lifecycle. The WLCA studies are mostly not understood by different stakeholders and are less effective in reducing the Global Warming Potential (GWP) impacts in the development of regeneration scenarios. This paper is part of a larger study on a multistakeholder lifecycle-based sustainability assessment framework and aims to further explore whether retrofitting can outperform the existing and new build scenarios for lower GWP impacts, and intends to examine the use of WLCA for the development of a regeneration scenario. The research consists of a single-case case study employing co-design workshops, surveys, and WLCA experiments. The community's preferred regeneration scenario has been developed through knowledge mobility and co-design workshops with the members of the community and a UCL team of designers and researchers. The WLCA of different regeneration scenarios (existing building, different refurbishment scenarios, and a previously approved redevelopment scheme) has been conducted using the data from desk-based research, site surveys, building regulations, retrofit case studies and guidelines, and the planning documents of the council's previously approved new build scheme. The results of the WLCA support the current studies in favour of the refurbishment scenarios over the demolition and rebuilding of the estate, and make a case for the necessity of understanding the GWP in design development to reduce the GWP of regeneration scenarios.
Keywords—Whole Life Carbon Assessment; Life Cycle Assessment; Housing Estate Regeneration; Participatory Processes; Community-based Research

1. Introduction

Since entering the Paris Agreement (COP21) in 2015 [1], UK has been the first nation to pledge to reduce its net greenhouse gas (GHG) emissions by 100% by 2050 compared to 1990 levels [2]. The considerable proportion of the estates' housing stock in the UK [3] has resulted in increased research imperative on decision making for regeneration to be centred around GHG emissions of the schemes. Carbon emissions (CO_2 or equivalent - CO_2e) is a metric measure for comparing the GHG or global warming potential (GWP) of different scenarios, also referred to as Climate Change Impact [4]. In the UK, one of the most established guidelines in the industry is the RIBA 2030 Climate Challenge [5] which introduces 2030 targets for new and existing dwellings for annual operational energy to be less than 35 kWh/m^2 and for the whole life embodied carbon target of less than 625 kgCO_2e/m^2. To quantify and reduce carbon emissions, a lifecycle-based approach is needed [6]. Whole Life Carbon assessment (WLCA) is the methodology used to calculate the carbon emissions of buildings over their lifecycle [7]. Some of the lifecycle-based studies comparing refurbishment against new build have shown the CO_2e saving of refurbishment scenarios [8; 9]. This is due to the low embodied impacts of reusing the building structure and materials, and improvements in operational energy performance by upgrading the energy systems and thermal properties of the building fabrics [8; 9]. Despite previous research, it is still widely accepted that the majority of new build options achieve better energy performance compared to the existing building stock [10].

In order to reduce CO_2e, WLCA needs to be introduced in the design process as early as possible [11]. To promote informed decision-making, stakeholders should be able to understand the overall impacts of different regeneration schemes [12]. In practice, this approach is not always employed. In addition to the social benefits of engaging with the stakeholders in decision-making over regeneration, many researchers have addressed the environmental benefits of such participatory practices [13; 14; 15]. Moreover, inclusive planning and engagement with the communities for decision-making are mandatory legislative requirements [16]. To build upon the existing research on GWP of different regeneration scenarios and engage with the stakeholders in understanding GWP impacts for design development, this research has conducted a mixed methods case study on a London estate. The research aims to further explore two questions: 1) Can retrofitting outperform the existing and new build scenarios for lower GWP impacts? 2) Does understanding GWP impacts affect the stakeholders' decision-making in developing regeneration scenarios? To enable carbon reductions and allow informed decision-making, different regeneration scenarios should be included in the WLCA and the stakeholders should understand the results of the WLCA. This study aimed to identify the whole life GWP impact of different regeneration scenarios of a case study and embedded WLCA for engaging with the stakeholders in design development.

2. Materials and Methods

This study is conveyed in a single-case case study involving qualitative and quantitative approaches to data collection and analysis. The first part of this study was a collaborative research project between a team of UCL researchers [17] and the community group of Alton Estate, with the aim of co-designing the People's Plan, which was the community plan for the regeneration of Alton Estate. The second part of the study has explored the WLCA of the community plan compared with other regeneration scenarios. Research methods consisted of co-design workshops; WLCA studies; desk-based research, and site surveys.

2.1 Community-led Design Development

Through online co-design workshops, the estate's regeneration community plan was developed by the community of the estate and the team of designers and researchers from UCL [17], in response to the council's approved scheme at the date. Two sustainability workshops were conducted with different stakeholder groups and one workshop with the UCL team to further discuss the technical aspects of the community plan. At the sustainability workshops, the participants were introduced to some of the environmental impacts of different building materials and systems. For the selection of building materials, the lifetime impacts of different materials were explained and compared at the workshops. For the selection of some of the building systems, the operational properties of those building systems were discussed. The workshop evaluation results yielded the significant impact of learning about the GWP impacts on the participants' decision-making for development of the regeneration scenario, as 88% of 17 respondents of the evaluation survey noted that learning about the carbon footprint of materials and systems impacted their decision-making over the selection of different options.

2.2 WLCA of Community Plan

Following the selection of building materials and systems at the sustainability co-design workshops, WLCA of different scenarios were undertaken. A four-storey maisonette as one of the most dominant building typologies of Alton West was examined for the case study.

2.2.1. Design Scenarios. The collective final decision for this block in the community plan was the moderate refurbishment of the existing building with a one-story extension on top. To compare different regeneration scenarios, 5 scenarios were explored for undertaking the WLCA (Table 1).

Table 1. Summary of the five explored regeneration scenarios for the case study

Scenario	Description
1	Existing building
2	Basic retrofitting of the existing building to meet the building regulations
3	Limited retrofitting of the existing building
4	Community plan (moderate retrofit of existing building with top floor extension and added balconies)
5	New build replicating the community plan

2.2.2. Data Collection and Tools. The available data on the existing building construction and materials attached to the planning application of the regeneration scheme of Alton Estate is very limited. Thanks to the help of staff at English Heritage, some data has been extracted from a 1959 issue of Architects' Journal [18]. Further data has been collected from our site surveys. Autodesk Revit [19] software has been used for modelling the building block which has been then exported as a gbXML format to DesignBuilder [20] software for a user-friendly EnergyPlus interface in preparation for conducting the energy simulations. Due to the limitations of an energy model for conducting WLCA, a more detailed model has been developed in Revit in parallel with the energy model, defining the same assembly build-ups and values but in more detail. The completed Revit model has been exported to One Click LCA [21] for conducting the embodied carbon simulations of the schemes over 60 years. The processes have been employed for modelling all regeneration scenarios.

2.2.3. Modelling Parameters. The building components and systems used for the assessment include substructure, superstructure, finishes and building services. **Table 2** illustrates a brief summary of the specification of major building components and heating, ventilation and air conditioning (HVAC) systems and the sources of material for each building scenario.

Table 2. Summary of the assumptions for WLCA

	Scenario	1	2	3	4	5
	Modelling Reference	The Energy Model, Cross-referenced with Site Survey and the Stock Model	To meet the Building Regulations Requirement [22]	LETI Best Practice Guidance – Limited/Constrained Retrofit [9]	LETI Best Practice Guidance - Moderate/Uncon-strained retrofit Element Method [9]	Energy Statement of Approved Regeneration/-Rebuild Specifications [23]
Major External Wall Type	Description	Brick Flank Wall 343mm; Outermost 2 Coat Perlite Plaster; Innermost Gypsum Plaster 12.5mm	Brick Flank Wall 343mm; Outermost 2 Coat Perlite Plaster; Internal Gypsum Plaster 12,5mm; Mineral Wool Internal Insulation 34mm; Vapour Control; Plasterboard Lining 2x12.5mm	Brick Flank Wall 343mm; Outermost 2 Coat Perlite Plaster; Internal Gypsum Plaster 12,5mm; Mineral Wool Internal Insulation 34mm; Vapour Control; Plasterboard Lining 2x12.5mm	Brick Flank Wall 343mm; Outermost 2 Coat Perlite Plaster; Internal Gypsum Plaster 12,5mm; Mineral Wool Internal Insulation 120mm; Vapour Control; Plasterboard Lining 2x12.5mm	105mm Brick; 185mm Mineral Wool Insulation; 105mm Brick; Plasterboard Lining 2x12.5mm
	U-value (W/m^{2}k)	1.48	0.32	0.32	0.18	0.18
Glazing	Description	Double Glazing (3mm/6mm Air Glazing) with UPVC Framing	Double Glazing with Alu Composite Framing	Double Glazing with Alu Composite Framing	Triple Glazing with Alu/Timber Composite Framing	Double Glazing with Alu Composite Framing
	U-value (W/m^{2}k)	1.96	1.60	1.30	1.00	1.30
External Door	Description	Timber Flush Door 910*2210*41mm	Timber Flush Door 910*2210*41mm; 6mm standard insulation	Timber Flush Door 910*2210*41mm; 25mm standard insulation	Timber Flush Door 910*2210*41mm; 35mm standard insulation	2mm Metal Door with 30mm Fibre Glass Insulation 910*2210*58mm
	U-value (W/m^{2}k)	2.59	1.80	1.00	0.80	1.00
Lowest Floor	Description	In-situ Reinforced Concrete Slab 180mm; Screed 40mm; Acoustic Quilt 30mm; Vinyl 2mm	In-situ Reinforced Concrete Slab 180mm; Screed 40mm; Acoustic Quilt 30mm; Vinyl 2mm	In-situ Reinforced Concrete Slab 180mm; Screed 40mm; Acoustic Quilt 30mm; Vinyl 2mm	In-situ Reinforced Concrete Slab 180mm; Screed 40mm; Mineral Wool Resin Bonded 20mm; Wood-derivatives cellulosic insulation 180mm; Hard Rubber 10mm	Precast Reinforced Concrete Slab 225mm; Screed 75mm; Mineral Wool Insulation 220mm; Floor Finish 20mm
	U-value (W/m^{2}k)	0.54	0.54	0.54	0.15	0.13
Roof	Description	Plaster 25mm; In-situ Reinforced Concrete Slab 180mm; Cork Insulation 25mm; Felt; 2 coats of asphalt 2x20mm	Plaster 20mm; Internal Mineral Wool Insulation 100mm; In-situ Reinforced Concrete Slab 180mm; Cork Insulation 25mm;	Plaster 20mm; Internal Mineral Wool Insulation 100mm; In-situ Reinforced Concrete Slab 180mm; Cork Insulation 25mm;	Plasterboard 12.5mm, Wood Derivative Cellulosic Insulation 100mm; Air gap 200mm; Glass Wool Roll 222mm;	Plasterboard 12.5mm; Wood Derivative Cellulosic Insulation 100mm; Air gap 200mm; Glass Wool Roll 197mm;

			Felt; 2 coats of asphalt 2x20mm	Felt; 2 coats of asphalt 2x20mm; Mineral Wool Insulation 150mm; Bitumen 2mm	Asphalt 10mm;	Asphalt 10mm;
	U-value (W/m^{2}k)	0.83	0.26	0.12	0.12	0.13
Heating	Description	Combi Boiler	Combi Boiler	Heat Pump	Heat Pump	Combi Boiler
	Efficiency(%)	85	88	250	250	89.5
	Fuel	Natural gas	Natural gas	Electricity from grid	Electricity from grid	Natural gas
Ventilation	Description	Natural ventilation	Natural ventilation	MVHR	MVHR	MVHR
	Effective-ness (%)	-	-	94	94	94
Airtightness	m^3/m^2.h@50Pa	25	10	3	2	3
Regenerative	PV % of roof area	-	-	-	40	40

2.2.4. WLCA System Boundary and Data Sources: The system boundary for WLCA is cradle to grave, consisting of modules A-C of whole life building life cycle including A1-A3 Product Stage, A4-A5 Construction Stage, B1-B5 Use Stage, and C1-C4 End-of-life Stage, based on EN15978 building lifecycle modules [24], excluding modules B1 to B3, and B7. The service life of the components has been based on RICS' guidelines [25] and it has been assumed that the materials will be replaced at the end of their service life. The source of environmental data is the Environmental Product Declarations from the One Click LCA database. Transport distance for the new materials has been based on regionally applicable assumptions from the software.

The WLCA simulation results were exported to Microsoft Excel for graphical and statistical analysis of the data. For validation of energy calculations in option 1 (existing building), the outcome of the simulations has been compared to the actual energy consumption of some residents.

3. Findings

3.1 Operational Energy

The results of the energy modelling unveil the annual energy use intensity (EUI) kWh/m^2 for each scenario. The analysis shows that the lowest energy demand belongs to scenarios 3 and 4. These scenarios are fossil-fuel-free with heat pumps for space heating and DHW, using electricity from the grid; and have lower U-values for external building elements, as presented in Table 2. It can be understood from the results of scenarios 1 and 2 illustrated in **Figure 1** that by applying a minimum level of upgrade to the existing building's fabrics, the energy consumption of that regeneration scenario can considerably be improved by almost 50% (from 164kWh/m^2 to 84kWh/m^2). **Figures 1** and **2** illustrate the annual distribution of fuel demand and EUI of different scenarios normalised by Gross Internal Area (GIA) (m^2). These findings provide evidence against the widely accepted hypothesis that the energy performance of new build schemes is better than retrofit scenarios. The findings are less surprising if we consider that gas boilers for heating and domestic hot water (DHW) have been specified in the energy statement for the new build scenario according to the planning documents [19].

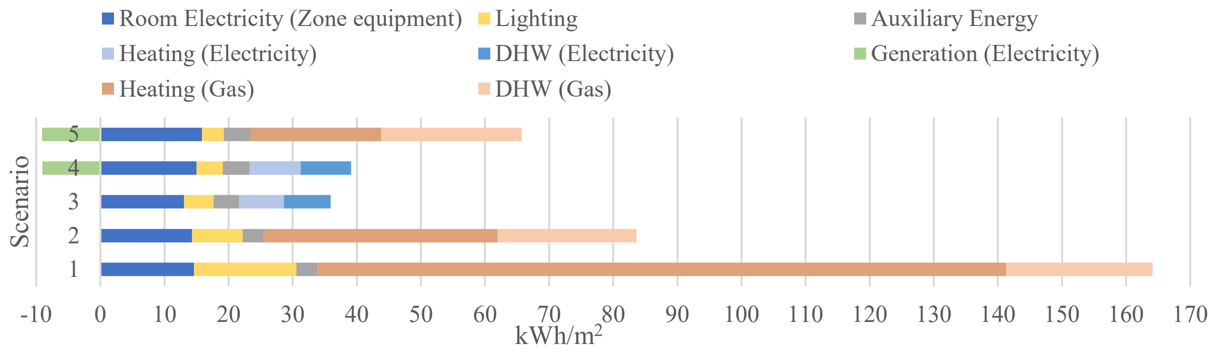

Figure 1. Annual distribution of fuel demand of regeneration scenarios normalised by GIA m^2

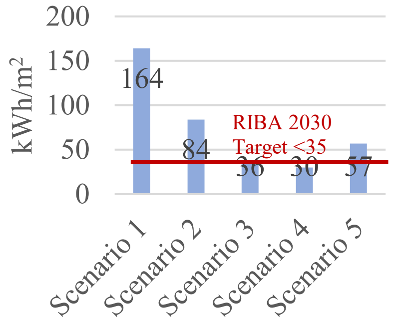

Figure 2. EUI kWh/m^2 per annum compared to industry benchmark

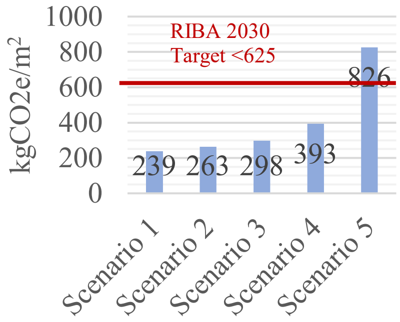

Figure 3. Whole Life Embodied carbon kgCO2/m^2 compared to industry benchmark

3.2 Embodied Carbon

Results of the analysis of the whole life embodied carbon of different scenarios normalised by GIA (m^2) expectedly yielded the high GWP of the new build scenario (scenario 5). As **Figure 3** presents, this regeneration scenario does not meet the RIBA 2030 target of less than 625 kgCO_2/m^2 (5). As described in section 2.2.4, the embodied carbon for the replacement of building materials and systems at the end of their lifecycle has been included in these calculations for all regeneration scenarios based on RICS' guidelines [25].

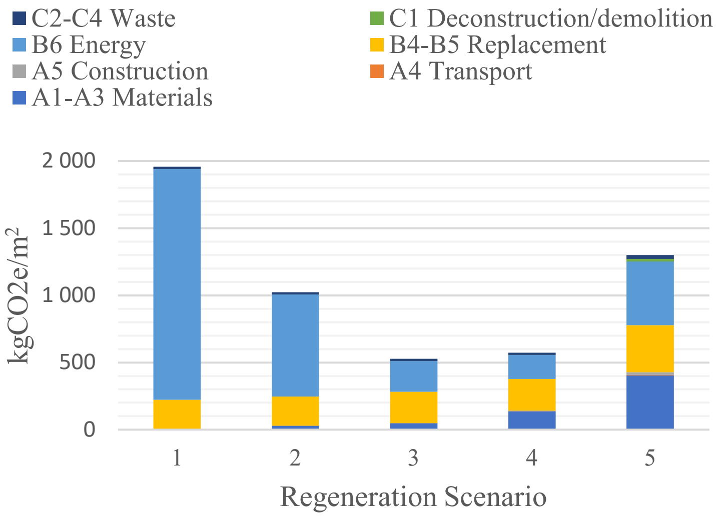

Figure 4. Comparison of the results of the WLCA of different regeneration scenarios over life cycle stages

3.3 Overall WLCA Results

The results of the global warming environmental impacts of different regeneration scenarios over the lifecycle stages have been presented in **Figure 4**. As the figure illustrates, Scenario 3 (retaining the existing building with limited constrained retrofitting) is the top ranking scenario in the overall WLCA results with the least overall impact. Although scenario 4 has better building fabric specifications, the addition of one storey to the existing structure has added to the overall GWP of this scenario compared to scenario 3.

4. Discussions

The findings of the WLCA of this case study provide strong evidence for the hypothesis that GWP of retrofit scenarios for the regeneration of housing estates can outrank a new build scenario as the results in energy consumption and whole life carbon can show considerable carbon emission savings of refurbishment scenarios. Although these results can be expected due to the modelling assumptions for each scenario, in practice most studies do not include scenarios 2 to 4 of this research that support retrofitting scenarios as the regeneration scenarios with the lowest GWP impact. It can be argued that the new build scenario in this case study had less energy efficient HVAC specifications than scenario 4. However, it should be noted that the specification for scenario 5 followed the planning application information [23], and the specification for scenario 4 adhered to the LETI guidance (9) for moderate retrofit but not the more rigorous deep retrofit scenario. It can be understood from the results that even with a fossil-fuel-free HVAC specification similar to scenarios 3 and 4, the overall impacts of scenario 5 would have stayed higher than scenarios 3 and 4, due to the high embodied impact of the new build scenario. These findings prove the insufficient legislative requirements as the results of WLCA of scenarios 2 and 5 demonstrate.

The communities often do not understand the GWP impacts due to the specialist nature of the WLCA studies. However, this research showed the interest of communities in understanding the assessment methodology and incorporating its findings in the development of the community plan. The results of the evaluation survey demonstrated that understanding the carbon footprint of different materials and systems highly impacted the community's decision-making.

The results of the case study reiterate that the retrofitting scenarios can outrank the new build scenario, especially where an integrated approach to GHG emissions encompassing both operational and embodied carbon emissions is adopted, and support the need for including retrofitting options in the comparison of different regeneration and redevelopment scenarios. The findings also support the impact of stakeholders' understanding of GWP impacts of materials and systems on the participatory development and exploration of regeneration scenarios.

5. Conclusion

This study provides an insight into the necessity of including retrofit scenarios in the WLCA studies of regeneration schemes, and transparently engaging with the communities in design development of estate regeneration scenarios. We recommend future studies to include more improved replacement scenarios in the WLCA comparisons, explore the quantitative carbon emissions saving impact of engaging with the stakeholders, involve wider scope of environmental and socio-economic impacts in the assessments, and include different stakeholder groups in the process.

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