Greenhouse Gases (GHG) Performance of Refurbishment Projects – Lessons from UK Higher Education Student Accommodation Case Studies

1. Introduction

There is growing scientific and political consensus that climate change represents the greatest environmental threat and challenge of modern times. The key driver of climate change is the robust link between the generation of greenhouse gases (GHG) and rising global temperatures (CCC, 2016). GHG emissions from UK buildings have been reported to contribute up to 37% of the UK's total GHG emissions (TSB, 2014). Notwithstanding GHG emissions generated during the design, material manufacture, distribution and on-site construction of UK buildings can reflect up to 18% of a building's whole lifecycle carbon footprint (BIS, 2010). A clear link has been identified between the whole life cycle environmental and GHG performance of a building and the focus and investment during the construction phase – for example less initial capital investment spent on insulation or plant may result in increased operation or maintenance expenditure and reduced environmental performance over the buildings whole lifecycle (Bribián et al., 2009). Therefore, if the UK is to meet its climate change targets whilst maintaining a vibrant construction sector, emphasis should focus on reducing the impact of buildings, and particularly construction practices.

The UK Department for Environment, Food and Rural Affairs (DEFRA) confirm that improvements driven by construction industry players will be crucial for reducing emissions (DEFRA, 2013). Considering that 87% of existing buildings in the UK will likely be standing in 2050 (UK GBC, 2016), a large focus of construction projects in the future will be retrofitting and/ or refurbishment of existing buildings. The Charted Institute of Building (CIOB, 2011), reported that the UK has about 30 million domestic and non-domestic buildings, of these 28 million will be required to be retrofitted or refurbished for the UK Government to meet it's carbon targets.

The importance of low carbon construction practices, refurbishment and maintenance works to reduce energy demands and GHG emissions are well reported (Ferreira et al., 2013; de Larriva, 2014; Killip, 2013). Simple retrofitting projects, such as adding thermal insulation to external walls, can provide higher energy efficiency and lower energy costs (Bojic et al., 2012), whilst major refurbishment can provide an opportunity to significantly improve poor energy performing buildings by replacing old items with new energy efficient materials and technologies (Carroon, 2010). Research such as that by Tang et al (2013) have also identified strong relationships between a project's GHG performance and the management focus and applied practices – different construction management strategies having significant influence on the overall GHG emissions generated over a project's lifecycle.

The UK has multiple guidelines, regulatory frameworks and incentive schemes that are designed to improve the standard of refurbishment and retrofit projects. Within the housing sector initiatives such as Decent Homes, Warm Front and Green Deal have each provided guidance and funding avenues for construction works (DCLG, 2006). Whilst in the private sector, greater autonomy is given to allow stakeholders to determine the best options of individual projects. The BREEAM Refurbishment (BRE, 2015), Considerate Constructors (CCS, 2015) and SKA rating (RICS, 2013) schemes are examples of benchmarking methods that are aimed at improving the environmental performance of construction and the resulting buildings. However, in the UK, the success of regulation and guidance for refurbishment has been widely criticised (CIOB, 2011; Killip, 2013; Rawlinson and Wilkes, 2014) and the uncertainties, risks and bespoke nature of refurbishment projects makes them inherently unsuitable for generic assessment schemes (Juan, 2009).

The student accommodation industry has emerged as the best-performing asset in the UK and US property markets (Hammond, 2013), with £1.85 billion invested in the UK in 2013 alone (CBRE, 2013) as the demand for student accommodation has continued to accelerate. Deloitte (2013) reported in 2013 that 1.72 million fulltime students are hunting for 457,000 purpose-built student accommodations in the UK. Non-domestic buildings are now being refurbished and converted into accommodation; and refurbishment of existing accommodation is rapidly in demand to meet student expectations. The UK student accommodation industry is considered a 'niche market', in which supply is adapted to meet the needs from students (considered as a specialised tenant group) (Rugg *et al.*, 2013), as demonstrated in Manchester (Carver and Martin, 1987) and Edinburgh (Nicholson and Wasoff, 1989). With highly anticipated growth within the niche student accommodation market (Savills, 2014), the construction sector is set to play a central role in determining the carbon footprint of these developments, where experience and good practices lessons will likely be key to increasing performance across the sector. As there is limited research into the carbon emissions of student accommodation refurbishment projects; this project aims to rectify this by:

1. Evaluate a series of exemplar comparative case study student accommodation refurbishment projects.
2. Analysis of the emission profiles of the comparative case study project's refurbishment works, focusing on how the characteristics of the projects may provide an indication GHG performance.
3. Develop conclusions for how GHG emissions may be best measured in student accommodation refurbishment projects.
4. Highlight important lessons for best practice for the construction sector.

In summary this paper aims to provide an analysis of the key performance indicators and GHG emission benchmarks for higher education student accommodation refurbishment projects, specifically for projects using JCT Design and Build Contracts (projects whereby the contractors are responsible for the building design in addition to the construction works; JCT, 2014).

2. Quantifying GHG Emissions

A myriad of methodologies have been developed aimed at quantifying the levels of GHG emissions from construction activities. These vary in terms of the method of calculation, and the choice of metric applied to estimate emissions (for example; transport distances, construction costs, material types, etc.). Methods include (1) quantitative approaches (Suzuki and Oka, 1998) for analyses that define set emission contributors; (2) analysis of interactions between direct and indirect energy uses and emission factors, for each subsection of work within a project (Acquaye and Duffy, 2010); (3) carbon emissions analysis by particle swarm optimisation (PSO) to evaluate optimal construction pathways with reduced environmental impact (Liu *et al.*, 2013). The metric of $kgCO_2e/m^2$/year is currently being drafted as the 'common carbon metric' by the United Nations Environment Programmes' Sustainable Building and Climate Initiative (UNEP, 2016).

Constructing Excellence (2014) has its own methodology to be applied when evaluating the UK construction industry's key performance indicators (KPI). KPI's are a systematic measure of an activities performance that allows the benchmarking, comparison against internal, competitive of generic targets (Constructing Excellence, 2016). To undertake KPI analysis, first the data has to be obtained during and/ or upon completion of a project should be collected that reflects: (i) the amount of energy used on site (electricity (kWh), diesel (litres), gas (kg)); and, (ii) the project value. Second, GHG emissions per energy usage will be determined using standard fuel emission factors as determined by the National Atmospheric Emission Inventory database (NAEI, 2016). Third, results are normalised with respect to the value, duration and context of each project so that they can be directly benchmarked against each other. The Constructing Excellence (2014) methodology is becoming the industry standard in the UK, and as such, this research analyses the respective data for the comparative case study projects. However, the Constructing Excellence methodology is largely based on overall project cost, and given its recent adage of 'cheapest is not always best', cost alone cannot be applied to decipher specific emission savings or issues. Therefore, this research builds upon the case study's Constructing Excellence data by also benchmarking emissions based on overall GHG Scopes, and the organisation's internal KPIs.

3. Methodology – Introducing the Student Accommodation Case Studies

This research engaged with a privately owned construction management company based in the North-West of England with projects across the country, with particular experience in student accommodation, hotels, social housing and schools. The company has a strong environmental focus that is integrated throughout their management systems, including a carbon management action plan developed in line with the principles of ISO26000 (ISO, 2010). A key element of company's core business is the management of projects including all contractors and sub-contractors. Therefore this company is well placed to provide indication of overall environmental impact of refurbishment projects and to provide an evaluation of GHG emissions generated both on and off-site during the refurbishment process. Four comparative cases were identified as projects representing typical UK student accommodation refurbishment works. Two of the case studies were long-term projects (more than 4 months duration) project and the other two case studies were short-term projects.

The clients for each of the case studies varied with each having differing requirements and project needs. A summary of the characteristics of the four student accommodation case studies is presented in Table 1. The projects were all developed under the JCT Design and Build Contracts.

[insert Table 1 here]

3.1 Project GHG Emission Datasets

Comparative GHG performance datasets for each of the case study projects were collected on-site through: organisational daily signing-in sheets (internal staff); sub-contractor daily signing-in sheet; delivery information; operational information for all machinery and equipment consuming fuels (eg. petrol, diesel, gas, etc.); as well as data reflecting all other activities and processes related to the projects. All accounted GHG's emissions are calculated in CO_2 equivalent values reflecting the values and methodology of the National Atmospheric Emission Inventory database (NAEI, 2016). Each project's emission data was collected on site and analysed on a periodic monthly basis where the data is reported by the organisation's Environmental Manager. An example of a project's emission data sheet is demonstrated in Figure 2. The GHG emission data for each of the comparative case study projects was guided by: the Greenhouse Gases Protocol for Project Accounting (WBCSD and WRI, 2003); the 3 tier Scope GHG classification framework; and organisational KPIs reflecting 5 themes (distance, duration, gross internal floor area, room numbers and value) as summarised in Table 2 - these 5 KPIs provide the basis of this research's analysis. The KPI's are typically used by the UK construction sector (UK Department for Business Innovation & Skills, 2015), and reflect those used by the organisation to measure and benchmark their construction performance.

[insert Table 2 here]

The comparative case study project datasets are presented in Table 3. These reflect performance data for each scope category of GHG emissions and for each of the organisational KPI's. Emission data is omitted for the first four weeks and final two weeks of the long duration projects (CS-1 and CS-2), and data from the first week and final weeks of the shorter duration projects (CS-3 and CS-4). This is to provide a more indicative and accurate picture of the emissions profile of the core activities associated with each project, and to allow better comparisons between the different datasets.

[insert Table 3 here]

3.2 Evaluation of the Comparative Case Study Project's GHG Emission Scope Data

Comparative analysis of the GHG emission scope datasets in Table 3 demonstrated that there were differences in emissions profiles across the case study projects. The breakdown of emissions within each GHG classification scope can be associated with the characteristics of each individual case study. For example although CS-3 and CS-4 are in the same city, there is great contrast in their emission profiles - the Scope 3 emissions for CS-3 are shown to be over 30% higher than those for CS-4, where a greater proportion of overall emissions are Scope 1. This reflects the higher proportion of sub-contracted work associated with CS-2 and therefore the out-sourcing of emissions. The proportional breakdown of Scope 1 and 2 emissions generated by projects CS-1, CS-2 and CS-3 are similar reflecting their comparative use of sub-contractors.

The indirect Scope 2 emissions reflect the use of purchased energy across all the projects - this data shows much greater consistency. Projects CS-3 and CS-4 demonstrate the least Scope 2 emissions, reflecting the short periods of onsite works associated with these projects and therefore less energy purchased. Differences in the proportion of Scope 2 emissions associated with CS-1 and CS-2 (both have long on-site refurbishment durations) may be attributed to the implementation of a new carbon action plan before CS-2, which increased the organisational focus on on-site energy saving practices/ technologies.

The refurbishment phase data (RP) presented in Table 3 demonstrates congruency between the datasets. These datasets provide more accurate representations of the GHG impact of the actual refurbishment works, as estimated emissions associated with the project's start-up and move-out works are excluded.

3.3 Evaluation of the Comparative Case Study Project's KPI Data

The case study projects could be categorised in two distinct groups based on their project characteristics, as shown in Table 2. CS-1 and CS-2 reflect projects with comparatively large duration of site, project value, internal floor areas and with the highest number of rooms. Whereas CS-3 and CS-4 are located further away from the organisational head office, they are much smaller in size and value and have much less onsite refurbishment duration. The KPI emissions data documented in Table 3 can be analysed to evaluate relationships between the project's characteristics and their emissions profiles.

The distance KPI data demonstrates that more emissions are generated by projects CS-1 and CS-2 despite CS-3 and CS-4 being greater distances from the organisational head office. This indicates that distance from the organisational head office may not be the strongest KPI to provide an indication of a project's GHG emissions. Analysis of both the duration KPI data and the value KPI data highlights the trend that greater emissions are generated by projects CS-3 and CS-4, despite projects CS-1 and CS-2 reflecting much longer duration of onsite refurbishment works and greater project value. Greater understanding of the influence of these KPI's may be gained through accepting that short term projects require the same number/ amount of start-up and move-out equipment, transport and support as any other project. In addition, short-term projects often require a higher number of operatives on-site to complete the project within the allocated timescale. This is confirmed through comparing the whole life cycle (WLC) emission data with the refurbishment phase (RP) data for these KPI's in Table 3. When estimated emissions associated with the set-up of a project are not considered (comparing RP data instead of WLC), the disparity between the datasets is much reduced and therefore the duration and value KPI provide a fairer reflection of the projects emissions. Although the shorter duration projects are still shown to document proportionally greater emissions compared to the longer duration projects. Therefore, working to tighter schedules and involving larger teams to achieve this may result in proportionally higher project GHG emissions.

Evaluation of the emission data for the GIFA and rooms KPI's highlight further trends. The room KPI data clearly demonstrates that projects CS-1 and CS-2 each with a large number of rooms reflect proportionally higher GHG emissions than CS-3 and CS-4 that each has lower numbers of rooms under refurbishment. The room KPI could therefore be construed as a close indicator of potential scope category of GHG emissions, and in this research where the analysed projects are student accommodation (typically highly cellular with a large number of rooms) this KPI provides a good indication of each project's scale. In reality, rooms can be highly variable in size and therefore a GIFA KPI may represent a more accurate reflection of the characteristics of a project, and thus an indication of GHG emissions. The GIFA emission data in Table 3 highlights that there are only marginal differences in GHG emissions generated across the case study projects. This difference is reduced further when comparing just the case study RP data.

It has to be assumed that an organisation working on multiple projects and implementing the same work practices on each, should generate comparatively similar emissions from project-to-project / site-to-site, driven largely by the extent of work undertaken, not changes in work approach. Other potential attributes to why longer duration projects perform better include economies of scale (e.g. less transportation involved, improved learning curve for staff, and minimised fixed environmental costs for instance). The least variation in emissions profile across the case study projects is demonstrated by the GIFA KPI datasets. GIFA may therefore represent the most accurate indicator of a project's characteristics, and thus the levels of emissions that may be generated if the same organisation (works practices) completes the project.

3.4 Evaluation of the Performance of KPI's to Reflect Project GHG Performance

A further analysis stage that may be undertaken using the case study project's emission data is investigating the ability of each KPI to reflect the different project's GHG impact. Independently each of the KPI's provides an indication of the project's GHG performance, and allows the projects to be benchmarked against each other.

Figure 1 has been designed to allow comparison of the GHG performance of each case study project according to the different KPIs. The values presented for each KPI have been normalised so that the different datasets may be presented on the same scale. The stacked column charts provide a breakdown of the whole lifecycle and refurbishment phase GHG emissions for each project and allow the performance of each to be benchmarked against the other projects. The value labels across Figure 1 highlight the rank of each project in terms of GHG performance for each KPI. Projects ranked 1 for each KPI are those with the greatest GHG impact, and likewise projects ranked 4 reflect the project with the least GHG impact according to the KPI.

[insert Figure 1 here]

As Table 4 highlights there is much variability in the comparable GHG performance of the different case study projects according to the different KPIs. CS-1 is identified as the project with the greatest whole life cycle GHG impact according to three of the KPIs (distance, GIFA and rooms), the other KPIs highlight CS-4 as the project with the greatest impact. There are fewer consensuses reflected by the refurbishment phase data, the GIFA KPI identifying CS-2 as the project with the greatest GHG impact. Contrasting trends are also demonstrated across the KPIs when determining the projects with the best GHG performance - projects CS-2, CS-3 and CS-4 all being identified as the best performing projects according to different KPIs.

[insert Table 4 here]

In summary, the analysis highlights that there is significant variability in the ability of the different KPIs to reflect the GHG performance of projects. This confirms the importance of consistently using the same KPI when comparing the performance of multiple projects, and also that some KPIs may reflect greater representation of GHG performance than others based on the specific characteristics of the project. Statistical correlation analysis was undertaken to directly evaluate the relationship between the KPI characteristics of the research's projects and the resulting WLC and RP emissions generated. As Table 5 demonstrates high correlation is shown between all of the KPIs and GHG performance, highlighting that each KPI may be used in their own right to provide an accurate indication of GHG performance. Negative correlation is shown between the distance KPI and GHG performance, reflecting reduced proportional GHG performance with shorter distance for the comparative case studies analysed. In contrast the other KPIs for the comparative case studies analysed show positive correlation with GHG performance – as the proportional GHG performance per KPI improves as project duration, GIFA, room number or project value increase.

The correlation analysis in Table 5 highlights that the duration, GIFA and project value KPIs were identified as the most accurate indicators of a project's overall WLC emissions, and the duration and GIFA KPIs are the best indicators of a projects refurbishment phase emissions.

[insert Table 5 here]

Discussion

This research has analysed estimated refurbishment GHG emission data from an environmentally conscious organisation undertaking refurbishment works on four case study student accommodation projects. The aim of the research was to identify potential lessons that could be drawn from these projects for the wider construction industry, and to evaluate the methods in which the GHG performance of refurbishment projects are benchmarks and compared. Although the research's case study sample size is relatively small, the projects analysed reflect a broad range of characteristics and are a typical sample of UK student accommodation refurbishment projects (as the organisation has 8 years experience in operating within this field) – and therefore provide a valuable contribution to the wider research theme.

Project KPIs were derived and used in determining the likely levels of emissions that will be generated through undertaking refurbishment works. The duration and value of a project were found to be important indicators of potential emissions, although these may also be misleading when evaluating the comparative GHG impact of refurbishment works. The research finds that high value and long duration projects will result in larger overall emissions compared to lower value short-term projects. However, the nature of short-term projects having denser workloads and involving proportionally higher numbers of workers for the duration of the time on-site can result in the comparatively greater GHG impact across eachj emissions scope category compared to longer, higher value projects. This is particularly acute in student accommodation projects, as refurbishment work usually has to occur during student holiday periods when accommodation is usually vacant (such as Easter or Christmas which are short-term in duration, during the Summer months which is slightly longer), or planned in a phased-approach whereby students have to relocate during the term whilst refurbishment work is on-going.

In theory, both the GIFA and the number of rooms of a project should provide the best emission benchmark as they reflect the scale of work to be undertaken; but the research's data analysis has demonstrated otherwise. Due to the nature of student accommodation having a large number of rooms (variable student rooms, kitchens, foyers and landing area combinations, etc), using the number of rooms can be a misleading indicator of GHG performance. The research found that GIFA provided a more accurate reflection of potential GHG emissions for student refurbishment projects.

Evaluating the different scopes of GHG emissions data was found to be a useful tool for organisations to potentially monitor emissions from different contributors during the whole lifecycle of the project. The organisation has complete control of Scope 1 emissions (direct emission). The Scope 1 GHG data allowing organisations to measure manage and prioritise internal resources for the project, such as internal staffing numbers, business travel and accommodation provision. Scope 2 data (indirect emissions) is the direct representation of the generation of purchased energy used on-site, with lower Scope 2 data equates to less consumption and lower costs. Scope 3 emissions as those that the organisation will have the least control over as they reflect the emissions from outsourced activities not owned or controlled by the organisation. Analysing Scope 3 data can provide the organisation with the opportunity to improve supply chains, exclusively appoint only certified sub-contractors whom share the same environmental concerns, enhance wider social corporate responsibility and potentially reduce costs through requiring minimum environmental performance levels for all sub-contractors and suppliers.

As it stands most organisations only undertake internal comparisons and benchmarks of the GHG performance of their refurbishment works, in order to highlight potential improvements. A potential major issue faced by organisations can be the non-availability of common KPIs for comparison of GHG emissions. As this research demonstrates the ability of different KPIs to reflect potential GHG performance can be highly variable. Therefore, if organisations are determined to benchmark the GHG performance of their work with other competitors or partners, default KPIs need to be applied.

This paper only reports on the results of GHG emissions based on 4 comparative case studies from a single organisation. There are no readily available benchmarks for emissions for the refurbishment sector in the UK, let alone the student accommodation projects. Future development would further compare more refurbishment projects from other organisations and include elements of embodied energy within its building materials. Further, the UK sector is currently undertaking widespread refurbishment of social housing projects; therefore, findings from this research could be adapted and applied to the housing sector.

Conclusion

The student accommodation sector in the UK and US is the best preforming asset and is expected to grow further. The quickest method to satisfy demand is to refurbish current stock or change building use, however, little is known of its environmental impacts. The GHG emission data provides an opportunity to measure performance, set targets and a benchmark for refurbishment projects to evaluate their practices and learn lessons that may ultimately reduce the GHG impact of wider refurbishment. Project KPIs were predetermined - distance, duration, GIFA, rooms and project value - different KPIs were found to have varyingly ability to reflect the potential GHG performance of refurbishment projects. Based on the analysis and data from this research's case studies projects, the gross-internal-floor-area (GIFA) was identified as the KPI that best reflect the GHG impact of student accommodation refurbishment projects.

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