REDUCING EMBODIED CARBON IN THE CONSTRUCTION SECTOR

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The increasing drive towards net zero carbon has thrown a spotlight on 'embodied carbon' in the construction industry. Embodied carbon refers to the whole life carbon emissions associated with the materials used in buildings, and includes emissions arising from the resource extraction, material production, transport, installation, maintenance and end of life disposal. In the UK, embodied carbon associated with new construction accounts for 20% of annual carbon emissions from buildings. Reducing this is key to meeting the UK's commitment to achieve net zero by 2050. In this study, recent academic and industry literature on embodied carbon is examined, and interviews are held with nine industry professionals with specialist knowledge on embodied carbon. The findings show that against a background of increasing academic research and industry knowledge on the topic, there remains a lack of clarity over the guidance and methodology used to calculate embodied carbon. There is no comprehensive materials database for embodied carbon and no one calculation tool or approach used by the construction industry. A more coherent and agreed approach is needed if industry is to effectively reduce embodied carbon in new build construction and refurbishment. The UK has no clear legislative requirements or policy framework on the topic. Legislation is urgently needed to drive and incentivise embodied carbon requirements throughout the industry. Since most of the embodied carbon emissions of materials occurs before the construction phase, the focus must be on understanding the implications of material choices with a preference for material reuse where possible.

Keywords: carbon; embodied carbon; net zero; life cycle; sustainability

INTRODUCTION

The drive for net zero

In the UK, buildings may generate as much as 49% of total UK greenhouse gas emissions, (LETI 2020). Following commitments made at the 2016 Paris Climate Agreement, the UK Government has set a target to achieve net zero carbon emissions in the UK by 2050, (Harvey and Ambrose 2020). Prior to that, some groups had proposed that all new buildings designed from 2025, and all new buildings constructed by 2030 onwards, should be net zero carbon, e.g., LETI (2020), but the Government's announcement adds a policy impetus and has the effect of putting real pressure on the construction industry to reduce carbon emissions.

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The importance of embodied carbon
71% of building-related emissions are generated by heating, cooling, power supply power and other in-use activities. These are 'operational emissions'. The remaining 29% are generated in the production and supply of the materials used in the building, (WGBC 2018). Known as 'embodied emissions', these latter were produced before the product or material gets fitted or installed in a building and are therefore considered 'embodied' in the product or material itself, (Pomponi and Moncaster 2018).

For almost 45 years the construction industry has targeted reducing energy use in buildings. Spurred by the Energy Performance of Buildings Directive, (EU 2010), the UK Building Regulations have evolved to produce buildings that use less energy, and have lower operational emissions, (Pomponi and Moncaster 2018). However, until recently, embodied emissions were largely disregarded, and embodied carbon continues to be under-considered by designers, (Adams *et al.,* 2019). As buildings have become more energy efficient, the opportunities to further reduce operational carbon have reduced, and embodied carbon now represents a higher percentage of the whole life carbon emissions, (LETI 2020). This growing impetus to reduce emissions further, means increased focus on embodied carbon.

Addressing embodied carbon during building design
Reducing embodied carbon in new buildings means using less material, or using materials with lower levels of embodied carbon, (LETI 2020). Understanding the embodied carbon content of materials is key to this. A whole life approach considers the embodied carbon of materials and influences their selection. Such an approach is beginning to evolve, but uncertainty remains over what information and assumptions are being used, and how the calculations are being carried out, (De Wolf *et al.,* 2017). For many projects, the focus remains largely on cost and reducing operational carbon emissions during building operation, rather than a whole life carbon calculation.

The construction industry is still only beginning to account for embodied carbon, with progress evident only in some parts of the sector, (De Wolf *et al.,* 2017). Although guidance exists to calculate embodied carbon in construction, there are many variations on the approach to calculate it, (Säynäjoki1 *et al.,* 2017). The various data and approaches used make it difficult to draw comparisons between projects and may be one reason why the sector has been slow to adopt a strong approach to addressing embodied carbon. To compound the problem, there is no clear Government legislation or guidance that enforces or requires or regulates a whole of life approach to carbon, (Pomponi and Moncaster 2019). This halting and confused approach has hampered efforts to effectively reduce embodied carbon in new buildings, (Giordano *et al.,* 2015).

Aims of the study
The aim of this study is to examine how embodied carbon is currently taken into account in construction projects in the UK, and clarify what information and tools are available to calculate the embodied carbon content. It then identifies the steps needed to more effectively reduce embodied carbon in the construction sector.

RESEARCH METHOD

Academic and industry literature on carbon, embodied carbon and material carbon content was reviewed. Information was obtained from publicly available information on several recent projects on how embodied carbon was approached during design and material selection. A series of interviews was then held with nine industry professionals familiar with the topic of embodied carbon and practical experience in considering it in building refurbishment and new building design. The nine interviewees included an architect (A), a mechanical and electrical director (B), a mechanical and electrical engineering associate (C), a structural engineering director (D), a client project manager (E), a building developer (client) (F), a clients' building manager (G), a main contractor's director (H) and a design manager (I). The interviews were conducted in a semi-structured format centred around a set of key questions and allowing for follow-up to elucidate particular points. The interview responses were transcribed for coding and thematic analysis with the aid of the NVIVO software tool which uses thematic analysis to explore patterns in the data and which allows in-depth analysis of the interview transcripts. This is an established approach for drawing out information from practice and experience, (Braun and Clarke (2006).

LITERATURE REVIEW

Developing Industry Targets and Adopting a Whole of Life Approach

In 2017, the World Building Council set dual goals: 1. new buildings operating at net zero carbon by 2030, and 2. eliminating construction emissions by 2050 to achieve net zero carbon, (WBGC 2017). In the same year, the UK Green Building Council developed a framework called Advancing Net Zero, which emphasised the need to consider both the construction and operation stages in order to achieve net zero carbon buildings, (UKGBC, 2017).

In 2019, RIBA adopted its 2030 Climate Challenge Targets of reducing operational energy by 75%, and embodied carbon by between 50% and 70%, using a whole life carbon approach, (RIBA 2019). These aim to reduce the embodied carbon in domestic buildings from a current benchmark of 1,000 kg CO2e[2] per m2, to 300 kg CO2e by 2030. For non-domestic buildings, the target is to move from the current benchmark of 1,100 kg CO2e per m2, to 500 kg CO2e by 2030, (RIBA 2019). RIBA (2019) considers that the methods for calculating embodied carbon to address these targets are widely established although this is questioned by industry practitioners, see later.

A whole life approach to carbon emissions considers both the operational emissions and embodied carbon emissions over the life of a project, (RIBA 2019). The five main stages to be considered are usefully defined in British Standard EN 15978, namely: 1. From resource extraction to material production (which includes raw material supply, transportation, and manufacture of the product); 2. Construction (which includes transportation to site, and the construction and installation processes); 3. Use (which includes use, maintenance, repair, replacement, and refurbishment); 4. End of life (which includes deconstruction and demolition, transport, waste processing, and disposal), and 5. The emissions and potential benefits arising beyond the boundaries of the project (which address the ability to reduce the quantities of materials used, as well as the potential for future recovery and recycling).

[2] CO2 equivalent, i.e. also taking other greenhouse gases into account in addition to CO2

A best practice approach would include setting initial targets for embodied carbon taking account of how much recycled material can be used in the building, and also considering the potential for future recycling of the materials used, (LETI 2020).

Available Guidance and Advice for Calculating Embodied Carbon

Several organisations have produced guidance on addressing embodied carbon. CEN: The European Committee for Standardization (CEN) published two standards - in 2011 and 2012 - to provide guidance and formalize methods for calculating whole life carbon, (BSI 2011) and (BSI 2012). These remain the core standards used today, although the effectiveness of even a such a formalised method of calculation depends on having reliable and accurate data, which the BS does not provide.

RICS: In 2017, RICS produced its 'Whole Life Carbon Assessment for the Built Environment', which was the first guidance in the UK on a whole life carbon approach to reducing emissions. It details principles and supporting guidance based on British Standard BS EN 15978:2011 and was felt necessary because the 2011/2021 standard left designers too much flexibility for interpreting the guidance. Morris (2018) is among those who question how effective the RICS guidance is for industry, given the underlying unreliability and inconsistency in the approach and assumptions used to produce the core data which the guidance needs.

RIBA: In 2017, RIBA published its 'Embodied and Whole Life Carbon Assessment for Architects'. This was produced to provide guidance specifically for architects on reducing carbon emissions by considering whole life carbon during design. Although this guidance contained the most consistent and detailed approach available within the construction industry and emphasised how decisions related to carbon must be rigorously interrogated at each stage of the project, (Sturgis 2017), it remains dependent on a reliable database of material information in order to be useful.

IStructE: In August 2020, the Institution of Structural Engineers released a document 'How to Calculate Embodied Carbon,' which provides principles to guide structural engineers on how to complete embodied carbon calculations, (Gibbons and Orr 2020). The guidance aims to produce robust consistent calculations to enable meaningful comparisons to be made across projects. The guidance focuses on specifying materials that produce an overall reduction in the carbon used in each project, as well as highlighting the benefits of low carbon design to clients. The document aligns with and supports the sustainability elements of the Structural Plan of Work 2020, the RIBA Plan of Work 2020, (Yates 2020). This is a positive development although significant choice remains in the selection of assumptions needed for the calculations.

CIOB: The CIOB has developed a Carbon Action 2050 toolkit which aims to provide simple guidance to members of the CIOB and the wider construction industry. The toolkit focuses on cutting carbon emissions by using innovative, best practice techniques on design, construction, maintenance, operation, and waste management as well as a strong focus on the refurbishment of existing buildings, (Crane, 2020). Like the RICS guidance, parts of this toolkit are open to interpretation and allow some leeway in the assumptions and application.

LETI: The London Energy Transformation Initiative (LETI) is a voluntary group of over 1,000 industry professionals established in 2017. LETI has produced guidance to industry in progressing towards net zero carbon, but focusing specifically on the London area, (LETI 2020). LETI's recommendations to the Greater London Authority have been incorporated into it policy guidance and it has pushed for embodied carbon to become part of legislation to achieve net zero carbon. This legislation has not yet been introduced, and anyway needs to introduced UK wide not just within London.

Databases and Tools for Calculating Embodied Carbon

The Inventory of Carbon and Energy (ICE) was created to compile data on embodied carbon from both primary and secondary public sources, (Hammond *et al.,* 2011). Although this is widely used, Sturgis Carbon Profiling LLP has been analysing materials carbon emissions since 2007 and considers that many challenges remain in assessing embodied carbon, not least that there was still not one comprehensive database that industry can use as a data source on embodied carbon in materials, (Sturgis 2017), which can lead to inconsistencies when comparing projects.

More recently, Hawkins Brown architects in collaboration with UCL have developed the emission reduction tool H\B:ERT, (Hawkins Brown 2020). This is a Revit-based tool which measures the volume of each material within the digital model and applies data on the embodied carbon content to each. This tool addresses the production, construction, use and end of life, and therefore aligns with BS EN 15978:2011. It aligns with latest RIBA and RICS guidance and uses the data from the ICE database while also allowing the input of other data, which is key for enabling a meaningful comparison between construction projects.

The structural and civil engineering practice Heyne Tillet Steel (HTS) has also developed its own plug-in tool to use embodied carbon data from Environmental Product Declarations (EPDs) and the ICE database, (Furminger and O'Riordan 2020). HTS continues to develop embodied carbon and guidance tools within its own team and has also examined where it could alter its construction methods to reduce embodied carbon, (Furminger and O'Riordan 2020). Although the progressive tools developed by Hawkins Brown and Heyne Tillet Steel highlight how architects and engineers are reacting to the need for an embodied carbon tool, there is still the opportunity for inconsistencies without one tool that is used industry wide. This raises question if there could ever be one tool used by all.

Conclusions from the Review of Literature

Despite the increasing amount of guidance available, there is still currently no one comprehensive database that industry can use on the embodied carbon content in different materials, and the different approaches to a life cycle assessment make it difficult to make comparisons between projects, (De Wolf *et al.,* 2018). RIBA notes that although the methods for calculating embodied carbon are widely established and that RICS provides data for embodied carbon for the whole of life carbon content of materials, and that the number of EPDs for construction materials is increasing, (Anderson 2019), there is still not one agreed approach that professionals in the construction industry use to calculate embodied carbon, (RIBA 2019). Both Hawkins Brown (2020) and Furminger and O'Riordan (2020) also note that the lack of standardised measurement tools being used has resulted in industry professionals developing their own tools and ways to collect the data on materials.

Key to calculating embodied carbon is obtaining accurate data on the embodied carbon content of materials. This data is derived from assumptions and can be difficult to obtain and interpret. There is also an overall lack of transparency regarding the data on embodied carbon. Smith (2020) argues that only when all parties in the supply chain are transparent and accountable for the emissions at each stage in the material cycle, can a complete understanding be made of the levels of emissions generated, and the steps identified to reduce embodied carbon in each project.

These conclusions were used to design the primary data collection stage.

RESEARCH FINDINGS

From an analysis of the literature and the interviews, several issues have emerged relating to how embodied carbon is addressed.

Database limitations
Interviewees B and C highlighted significant limitations with the widely used Inventory of Carbon and Energy (ICE) database. They note that database is neither current nor clear, particularly for timber-based materials, cross-laminated timber, Glulam and other materials for which the database has no data. Interviewee A highlighted the large number of assumptions that need to be made, and interviewee C estimated that the assumptions made on material data can be wrong by as much as 20%. Interviewee B noted that while the concrete and steel industries have their own data sets, there is no one common database. Interviewee B suggested that a European classification on embodied carbon would help. Interviewee D noted that he used one data source for part of a project, and others for the remainder, highlighting again the lack of a single source of data. These comments support the concerns raised in the literature that a more comprehensive dataset is needed.

Collaboration and transparency over sharing of data within the industry
The literature highlighted a lack of collaboration, transparency, and willingness throughout the construction industry to share information, which must be overcome if accurate data on embodied carbon is to be created, (Smith 2020). Interviewees B, C, D and E confirmed this, and interviewee D noted that it is worse with design and build projects where the contractor may use alternative materials to what was specified, without informing the design team, leading to the assumptions made at design stage being incorrect, adding 'currently there is not one main data source, instead lots of companies are creating their own databases and not sharing information'.

The literature revealed the increasing use of EPDs and the interviewees confirmed that these are used where available. However, the suppliers often show little interest in calculating the embodied carbon content of their products. Interviewee H noted that only one cement supplier in the UK was willing to provide the required information on embodied carbon for a particular project.

Therefore, although data is available on embodied carbon for some products, it is not available for all construction materials. Suppliers need to ensure that all products have EPDs as these are key data sources for the calculation of embodied carbon.

Multiple calculation tools and approaches
Several tools are used to calculate embodied carbon. The literature cited that One Click LCA and eTool are used (Hawkins and Mumovic 2014), but revealed that several engineering and architecture practices have started to develop their own calculation tools (e.g. Furminger and O'Riordan 2020). One downside to the variety of tools is that each one uses different assumptions, sources of measurement, and approaches to the calculation, which results in variations in the embodied carbon figures, (Säynäjoki1 *et al.,* 2017). The experts confirmed this, with Interviewee D highlighting that this reduces the ability to compare projects and hinders the progression of the reduction of embodied carbon. IntervieweE said 'there still appears

to be a lot of assumptions made on data and little consistency when comparing projects'. This is a major implication for practice and the UK construction industry.

Reducing embodied carbon at the design stage

Both the literature and the interviewees confirm that the design stage provides the greatest opportunity to influence embodied carbon, and that this is the focus of the guidance developed by the professional institutions, (Sturgis 2017). There is evidence that designers are beginning to use EPDs, (Anderson 2019), and interviewee A confirmed that engaging sustainability consultants to address embodied carbon is becoming more common. However only interviewees B, C and D noted they are actively designing to reduce embodied carbon on any projects. This is yet to become widespread and is not common on smaller projects. None of the design consultants interviewed considered that industry is meeting its obligations to reduce whole life carbon. Interviewees A, B and D pointed to the fact that embodied carbon has only become a focus since around 2019 and emphasised that until addressing embodied carbon is backed up by regulatory requirements, there is no real obligation on designers to either calculate or reduce it on most projects.

Prioritising building refurbishment

Significant embodied carbon savings can be achieved if existing buildings retain the primary building structure, (Sturgis 2017 and Hawkins Brown 2020). The design consultants interviewed all agreed that refurbishment should be the first approach considered, rather than demolition and new build. Interviewee A highlighted how RIBA encourages architects to prioritise refurbishment, and interviewee B said 'Embodied carbon is easier to minimise in existing buildings'. Interviewee G agreed and said that re-using existing materials and refurbishment should be prioritised, as new buildings only introduce more carbon. The literature highlighted that as 70% of current residential houses will still be in existence in 2050, that these buildings will need refurbished rather than replaced, (Carbon Action 2050, 2020). This suggests that designers need to consider not only the building's operational use, but also its end of life, not designing how buildings can be demolished in a way that ensures the materials can be reused.

The need for policy guidance from Government

Although LETI and UKGBC have published general guidance on how the industry can achieve net zero carbon, this does not go as far as to include a calculation tool, data source or methodology. Even the 10-point plan issued by the UK Government in November 2020 contains no specified data source, tool or approach, (Goodwin, 2020). Although interviewees A, B and C have all followed specific guidance on how to address embodied carbon, the guidance produced by the various professional bodies is focused on the different professions. These interviewees consider that clear guidance is needed from policy makers and legislators, in terms of embodied carbon targets and reduction requirements, and in terms of acceptable data and assumptions that can be made, and on approaches to the calculations. Interviewees B and C referred to the past success of the Building Regulations in reducing operational carbon and were optimistic that a similar change in approach to embodied carbon could be achieved if the UK Building Regulations were revised. Interview H concluded that 'If the industry will not embrace embodied carbon voluntarily, it needs to be enforced through legislation and policy'.

CONCLUSION

This study has shown that the industry needs to improve its efforts to calculate and reduce embodied carbon. Despite the publication of BS EN 15978, there remains widespread lack of understanding throughout the UK industry on the importance of addressing embodied carbon. Despite a growing volume of guidance published by UK professional institutions for reducing embodied carbon, there is no comprehensive material database or one calculation tool used throughout the UK industry.

The research also suggests that the professional bodies need to collaborate to create a robust national database as a central, respected source for all industry disciplines. A clear agreed approach for calculating embodied carbon is also needed to reduce the variations and discrepancies in the calculations which hamper an honest appraisal of projects' carbon performance and enable comparison between projects.

It is clear that policy guidance is also needed. Government should set targets for embodied carbon, and policies encouraging circular economy principles at a building level should be incorporated into legislation. Changes are needed to the Building Regulations to include stipulations to reduce embodied carbon and to require a whole life approach to carbon, with the priority on using materials with low embodied carbon. This can be done by establishing a consistent methodology for calculating embodied carbon which allows comparison between projects.

The study also concludes that awareness and skills within the industry need raised and upgraded. Designers must learn to prioritise reuse and refurbishment in all projects before considering new build. EPDs should become standard for all construction materials. Designers must become experienced with whole life carbon reduction approaches and learn to account for embodied carbon as well as operational carbon, in order to understand where the largest savings can be achieved. Designers and contractors need to favour materials like low carbon concrete over more carbon intense products. Sustainable timber should be considered in far more applications as an alternative to other materials.

Clients must be encouraged to design and construct low embodied carbon projects, and to take low carbon capability into account when selecting the designer. Targets should be set and reviewed frequently between the client, design team, and main contractors. The contract documents should allocate responsibility for monitoring and reporting on all construction works demonstrating compliance with the original embodied carbon targets determined and set at design stage by the consultant team.

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