



# EMBODIED CARBON: ARE WE THERE YET?

White paper report

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## Overview

This paper was put together following the CBx breakfast event in March 2015, to show how as the construction industry learns to design and construct buildings with ever decreasing operational energy consumption, issues of embodied carbon becomes increasingly important in the whole life cycle costing of a building. Our panel of experts presented learning outcomes from case studies and highlighted any trip hazards to watch out for. Assessment software was also discussed as well as the relationship between embodied carbon and other environmental concerns in the lifecycle of a building.

With special thanks to our fantastic panel of experts; Christian Dimbleby, of Architype, David Mason of Skanska, Sean Lockie of Faithful+Gould and Mike Medas of AECOM.

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### INTRODUCTION

Embodied carbon has been a point of much discussion and academic research for some two decades but has only recently become part of the construction industry's wider agenda. Originally taken ownership by the Quantity Surveyor profession, it has now been adopted as an objective by the whole building cycle. As the built environment tends towards zero operational energy consumption, the embodied carbon of those buildings becomes increasingly important in comparison.

In 2014, the UKGBC ran an Embodied Carbon Week and produced a summary report capturing main themes and discussions of the event. Of the 15 challenges identified from attendees across the programme, the top 4 were; consistency in method, availability of comparable data, industry attitude – legislation not forthcoming and worry of extra cost and complexity. A year on, some headway has been made however, as the CBx embodied carbon event highlighted, these challenges are still ongoing.

***“The standardisation of embodied energy & carbon reporting is necessary to prevent merely shifting the time at which the energy is ‘spent’”***

### EMBODIED VS. OPERATIONAL

The main unintended consequence of the continued tightening of the Building Regulations' requirements for operational efficiency has been observed as the increase in embodied energy of those buildings. In many cases, designers will employ a high-tech approach in order to minimise operational consumption; using highly processed materials, complex plant equipment and a sophisticated, automated control system.

In terms of whole-life performance, this tends to shift the carbon 'cost' from operational consumption to the embodied carbon of the building fabric. The University of Bath, who produced the Industry's first authoritative database on embodied carbon of materials in 2005 (Inventory of Carbon & Energy – ICE), endorse the standardisation of the industry's reporting of embodied energy in order to prevent merely shifting the time at which energy is 'spent' and actually reducing the net carbon cost of any project.

***“In offices embodied carbon accounts for over half the whole life carbon cost, in supermarkets it is roughly 50% and in a semi-detached house it is much higher than 50%”***

The Royal Institute of Chartered Surveyors (RICS) produced a guidance document that sets out a method for the calculation of embodied carbon from cradle to end of life across four main sectors with case study figures for each. These illustrate that, over a 30 year period, around 50% of the total carbon is tied up in embodied (vs. operational) which includes the embodied carbon of the initial material, emissions during construction and the maintenance & repair cycle. Furthermore, the embodied vs. operational split differs from sector to sector with embodied carbon more pronounced in buildings housing low energy intensity activities such as warehouses; in offices embodied carbon accounts for over half the whole life carbon cost, in supermarkets it is roughly 50% and in a semi-detached house it is much higher than 50%.

### AVAILABLE DATA AND METRICS

In the main, the property industry is a laggard compared to the water industry whose regulator has required embodied carbon analysis of all assets since 2004. There has been development in determining

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carbon factors for pumps and other elements to facilitate accurate calculations for any replacement projects. Network rail and the highways agency also include embodied carbon calculations in their design, refurbishment and maintenance proposals. In many ways, embodied carbon calculations are much simpler within these industries as they comprise standard,

***“There is still a lot of uncertainty in embodied carbon values at the manufacturing stage and this creates difficulties for the contractor who must deliver against specifications assumed at design stage”***

modular components.

It's not all bad news though; things are progressing with a number of metrics and data sources and with BS 15978 setting framework for embodied carbon analysis. An EU standard published in 2011, BS 15978 is the standard upon which all Lifecycle Cost Analysis (LCA) is based and is now beginning to gain traction in the industry. The RICS method, previously mentioned, is a globally applicable process that simplifies Lifecycle Cost Analysis for the Quantity Surveyor community.

There are also a number of publicly available tools; the Environment Agency first published their embodied carbon calculator in 2007 and use this as one of three metrics upon which to judge a project. Architype released their bespoke calculator RAPIERE at Ecobuild last month (March 2015). These tools can also be mined for embodied carbon figures along with more conventional repositories such as the ICE database, the Franklin Andrews System and Black Book.

There is still a lot of uncertainty in embodied carbon values at the manufacturing stage and this creates difficulties for the contractor who must deliver against

specifications assumed at design stage. Further uncertainty is introduced where assumptions are made in terms of building use and refresh cycle. End of life details are also difficult to predict.

Currently, the industry relies on a few global averages but is expected that, in the future, more embodied carbon information will come from Environmental Product Declarations (EPD) - verified documents that report environmental data of products based on life cycle assessment (LCA) and other relevant information. Although only 7 EPDs exist in the UK, the US has hundreds already registered while Germany have close to 1000. Additionally, Building Information Models (BIM) will have embodied carbon capabilities, thus facilitating more accurate and less time consuming calculations.

***“In Westminster, embodied carbon mitigation plans are appearing on the radar”***

## DRIVERS AND LEGISLATION

On the whole, the drivers in the property space could be better. There is currently no embodied carbon requirement in Part L and in BREEAM there are one or two credits available per project. The Green Guide is tangentially linked to embodied carbon including the requirement as a proportion of an A-rating.

In terms of Local Authorities, Brighton Council was ahead of the curve, requiring an embodied carbon plan since 2011, however there is no record of the Council pushing for more stringent measures or holding applicants accountable against these. In Westminster, embodied carbon mitigation plans are appearing on the radar and the Department for Communities and Local Government (DCLG) are working on a white paper that investigates the potential for using Allowable Solutions as a mechanism for embodied carbon mitigation.

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### EMBODIED CARBON OF BUILDING SERVICES

Mike Medas has been researching the embodied carbon of building services as part of his Doctorate with Aecom and the University of Reading. In terms of building fabric, building services usually represent around 12-15% of total initial embodied carbon in an average

***“Due to operation, maintenance and replacement cycles and fit outs, over a life time building services can be responsible for as much as 60% of the whole-life embodied carbon of an asset. “***

modern office building. However, due to operation, maintenance and replacement cycles and fit outs, over a life time building services can be responsible for as much as 60% of the whole-life embodied carbon of an asset. These cycles are often extremely short and can be determined by a change of tenant / use as much as a need for replacement. This leads to equipment with high embodied energy being stripped and scrapped with as little as 6 years' service in some places. The Chartered Institute of Building Services Engineers have produced TM56 which aims to help engineers and consultants to understand the principles of resource efficiency for building services and set out opportunities to improve it.

While the property industry is beginning to develop methods and databases to deal with embodied carbon, there is a dearth of tools that address building services in any meaningful way. Accurate embodied carbon predictions are more difficult by the propensity for composite materials in building services; whereas the LCA databases are very much focussed on single raw materials. Again, it is possible the EPDs could fill this gap however their current voluntary status means that this is less likely to happen.

In response to this, and as part of his research, Mike is looking at the correlations and trends between the specification of a product or system and the magnitude of its embodied carbon in order to develop a method for prediction. Initial results from a case study of fan coil units suggest that the value of embodied carbon varies positively with mass and total cooling capacity.

### CASE STUDY: ECO MINIMALISM

Archetype, in a team led by main contractor Morgan Sindall, won the OJEU advertised design competition for the new Enterprise Centre building at the University of East Anglia. As part of the initial submission, the team had to provide a Passivhaus certifiable, BREEAM Outstanding design using local bio-renewable materials alongside a full carbon LCA.

With such stringent environmental performance standards stipulated by the client, a large- volume space with high levels of natural daylight, thick levels of natural insulation and triple glazed windows were applied. These aspirations had both positive and negative impacts on the embodied carbon. For example, under BREEAM there is a penalisation for the use of triple glazing; this was overcome by providing EPDs to retain material credits.

Due to the inherent contradiction in design aspirations – high fabric performance vs. low embodied energy – a

***“Under BREEAM there is a penalisation for the use of triple glazing – often essential for good operational energy performance”***

philosophy of Eco Minimalism was employed across the project. The design intent was for a completely timber structure in response to the embodied carbon brief however, due to unsatisfactory ground conditions, this was not possible and a ground slab was employed. This comprised 70% ground granulated blast furnace slag (GGBS) replacement and was polished in order to utilise

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it as the finished ground floor surface, thereby minimising materials.

Happily, where a higher fabric performance is achieved in the building envelope, this tends to minimise materials in services – for example; more insulation leads to fewer and smaller radiators – and this was the case in the Enterprise Centre. With respect to the embodied carbon of building services as discussed above, this will reduce the volume of high embodied carbon and composite materials in the design.

In terms of materials; the thatch, flint & aggregates were all sourced from the local area, additionally the majority of timber came from East Anglia potentially saving 91% of the transportation embodied carbon had the timber been conventionally sourced from Canada. Unfortunately in this instance it had to be processed in Ireland as local facilities were not available.. Site works have been carefully monitored for accurate recordings of energy used in construction; the contractor, Morgan Sindall, has also hired more expensive A-rated cabins in order to minimise this.

The team spent a lot of time calculating the embodied carbon of their bespoke materials and the lack of data led Architype to developing their recently launched software, RAPIERE, available this year, in 2015. Recycled site waste is also difficult to factor in to calculations; here Iroko lab benches from the adjacent building were recycled into external cladding.

### CASE STUDY: THE COMMUNICATION CHALLENGE

Skanska, a large multinational construction and development company, have up to 45 live commercial development projects at any one time alongside a chiefly residential portfolio in the Nordics and large-scale infrastructure projects.

‘Skanska Deep Green’ – is the 6-point Skanska sustainability agenda which includes ‘an ability to demonstrate near zero carbon construction’. This focus on near zero carbon construction means that the

interpretation of embodied carbon plans into reality must be carefully managed alongside other priorities. One of the big challenges is defining the baseline against which near zero carbon is measured and this is largely due to the complexities in benchmarking projects against a baseline.

In Norway, as much of their energy comes from hydro-electric sources, the focus has shifted from embodied carbon to embodied energy. The Powerhouse project is a refurbishment of a commercial office in Norway, designed to be energy positive and with an embodied energy payback date of 2070. Retaining the existing frame with a new, efficient façade and services strategy

***“One of the big challenges is defining the baseline against which near zero carbon is measured.”***

the project was able to keep embodied energy low. But the focus lead to innovative solutions such as the reuse of demolition waste in the new design. Benchmarking and comparison were a major challenge for the project and the whole team worked hard to achieve the final result.

In order for Skanska to clearly and simply communicate the importance of embodied carbon or embodied energy, a percentage saving must be conveyed; however this involves recalculating a conventional embodied carbon baseline bespoke for each project in order to compare against. This is time consuming and can be based on assumptions. Recently, Skanska have been looking at the prefabrication of utility cupboards and the calculated saving from moving the fabrication offsite, with further improvements possible in terms of improved design and a review of embodied carbon in the materials themselves. Again, they are finding the generation of a benchmark to calculate the benefits problematic as there is no ‘control’ utility cupboard

Skanska have faced other contradictions in their efforts to minimise embodied carbon. A concrete framed

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building was designed using 50% replacement with blast furnace slag and post tensioning was employed in order to minimise the volume of concrete in the elements. However, post-tensioned concrete makes safe deconstruction and effective reuse extremely difficult – providing yet more examples to substantiate the need for whole-life performance to be considered.

### FURTHER DISCUSSIONS

The true business case for embodied carbon is experienced by owner occupiers who are affected by both the CAPEX and the OPEX of an asset. A focus on embodied carbon dramatically increases the design costs of a project however, examples from infrastructure have shown that reducing embodied carbon can reduce cost. In these projects this often leads to removing material and / or associated labour however in buildings the situation is much more complex and a greater evidence and data base is needed to make consistent cost reductions; the Private Finance Initiative (PFI) market presents opportunities for good case studies. Furthermore, the industry needs to standardise the approach to embodied carbon benchmarking and communication of savings against inaction. Until this can be communicated effectively, it is difficult to provide a persuasive argument or to demonstrate the results of a focus on embodied carbon.

Many companies are beginning to use the shadow price of carbon in assessing any potential activities, leading carbon – both operational and embodied – to be included as part of the cost of delivering a project. Just this week, Microsoft have released articles on the first three years of their internal carbon pricing program and a related carbon fee investment fund. These activities have garnered \$10 million in annual energy savings; emissions reductions on the order of 7.5 million metric tons of carbon dioxide equivalents and 10.2 billion kilowatt-hours worth of new renewable energy investments. These stories reinforce the positive outcomes that are on offer in this field and provide case studies for industry to follow. Perhaps these methods

could be used by the property sector as internal tools to drive change?

### RESOURCES

1. UKGBC Embodied Carbon Week summary report. Available from:  
<http://www.ukgbc.org/resources/publication/embodied-carbon-week-2014-report>
2. Inventory of Carbon & Energy (ICE) Available from:  
[http://www.ecocem.ie/downloads/Inventory\\_of\\_Carbon\\_and\\_Energy.pdf](http://www.ecocem.ie/downloads/Inventory_of_Carbon_and_Energy.pdf)
3. RICS Methodology to calculate the embodied carbon of materials. Available from:  
[http://www.rics.org/Documents/Methodology\\_embodied\\_carbon\\_final.pdf](http://www.rics.org/Documents/Methodology_embodied_carbon_final.pdf)
4. BS 15978. 'Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method' Available from:  
[https://www.london.gov.uk/sites/default/files/GLA%20Construction%20Scope%203%20%28Embodied%29%20Greenhouse%20Gas%20Accounting%20and%20Reporting%20Guidance%20vFinal\\_1.pdf](https://www.london.gov.uk/sites/default/files/GLA%20Construction%20Scope%203%20%28Embodied%29%20Greenhouse%20Gas%20Accounting%20and%20Reporting%20Guidance%20vFinal_1.pdf)
5. Environmental Product Declarations (EPD). For information visit:  
<http://www.environdec.com/>
6. Proposals for Standardised Measurement Method and Recommendations for Zero Carbon Building Regulations and Allowable Solutions. Available from:  
[http://www.asbp.org.uk/uploads/documents/resources/Embodied%20Carbon%20Industry%20Task%20Force%20Proposals\\_June%202014\\_Final\[1\].pdf](http://www.asbp.org.uk/uploads/documents/resources/Embodied%20Carbon%20Industry%20Task%20Force%20Proposals_June%202014_Final[1].pdf)