RESEARCH REPORT

MAY 2010

RICS RESEARCH

Redefining Zero: CARBON PROFILING AS A SOLUTION TO WHOLE LIFE CARBON EMISSION MEASUREMENT IN BUILDINGS

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Research

STURGIS ASSOCIATES

About the authors

Simon Sturgis AADip RIBA

Simon Sturgis is Managing Director of Sturgis Associates, an award winning architectural practice. He has over the years developed a particular reputation for innovative design solutions in relation to the reuse and refurbishment of buildings of all types. This has led him to evaluate the way buildings are made, and how they can be designed for efficient reuse. Inherent in this has been a concern over the way materials are deployed in construction, which has in turn led to the development of Carbon Profiling. Simon is a member of the British Council of Offices Environmental Committee, the BCO International Committee, and the UK India Business Council. He has spoken on carbon issues in construction in the UK and internationally, most recently at the 2009 World Architecture Festival in Barcelona.

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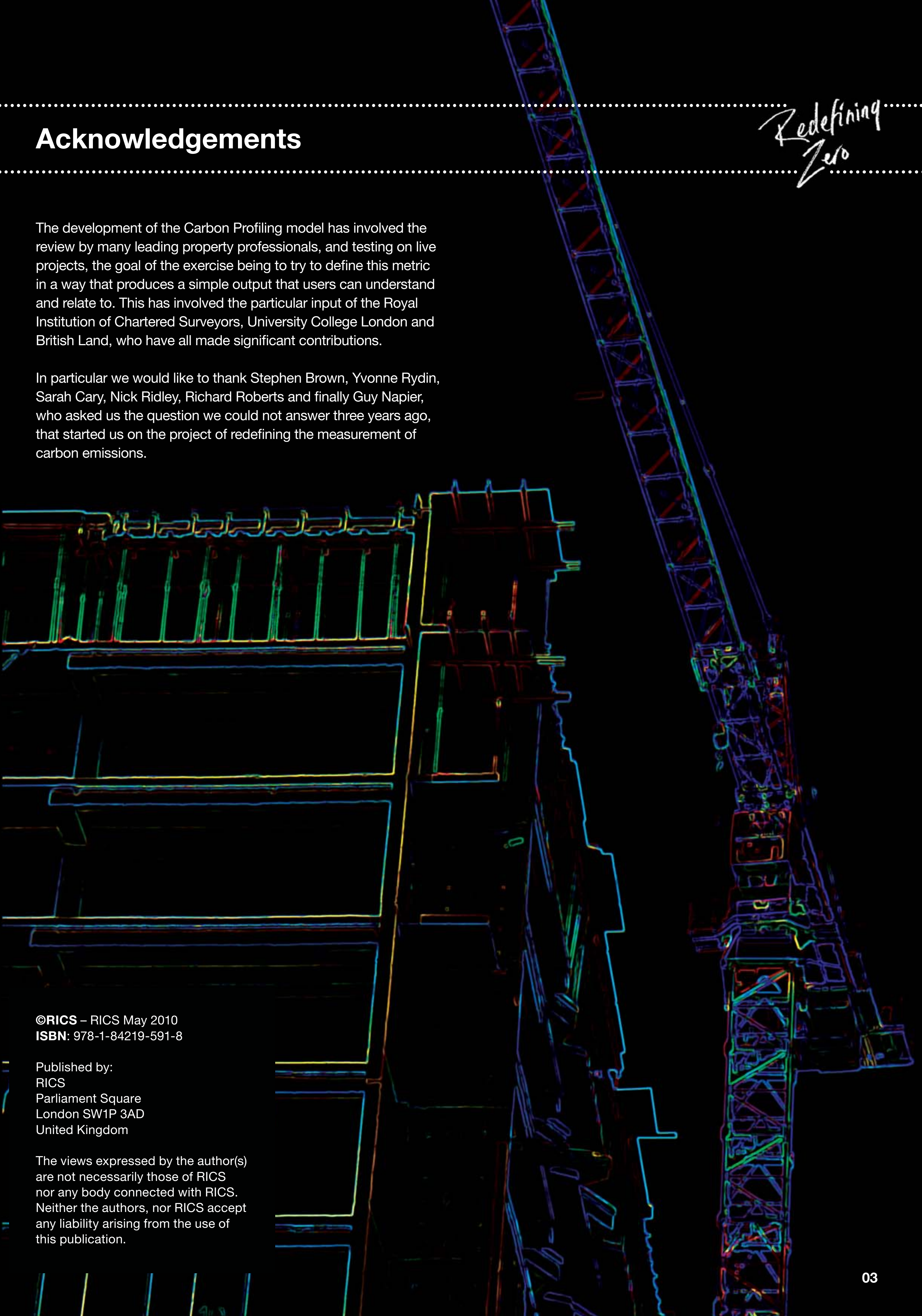
Since graduating in architecture from University College London, Gareth has been working in construction and building design for the last 9 years, on a range of residential and commercial projects in the USA, India and UK. Currently he is Head of Sustainability for Sturgis Associates in London where he is researching low carbon design solutions for the built environment, with a particular focus on the reporting of Embodied Carbon Emissions and Life-cycle analysis. He is carrying out a Masters in Real Estate Economics and Finance at the London School of Economics.

Acknowledgements



The development of the Carbon Profiling model has involved the review by many leading property professionals, and testing on live projects, the goal of the exercise being to try to define this metric in a way that produces a simple output that users can understand and relate to. This has involved the particular input of the Royal Institution of Chartered Surveyors, University College London and British Land, who have all made significant contributions.

In particular we would like to thank Stephen Brown, Yvonne Rydin, Sarah Cary, Nick Ridley, Richard Roberts and finally Guy Napier, who asked us the question we could not answer three years ago, that started us on the project of redefining the measurement of carbon emissions.

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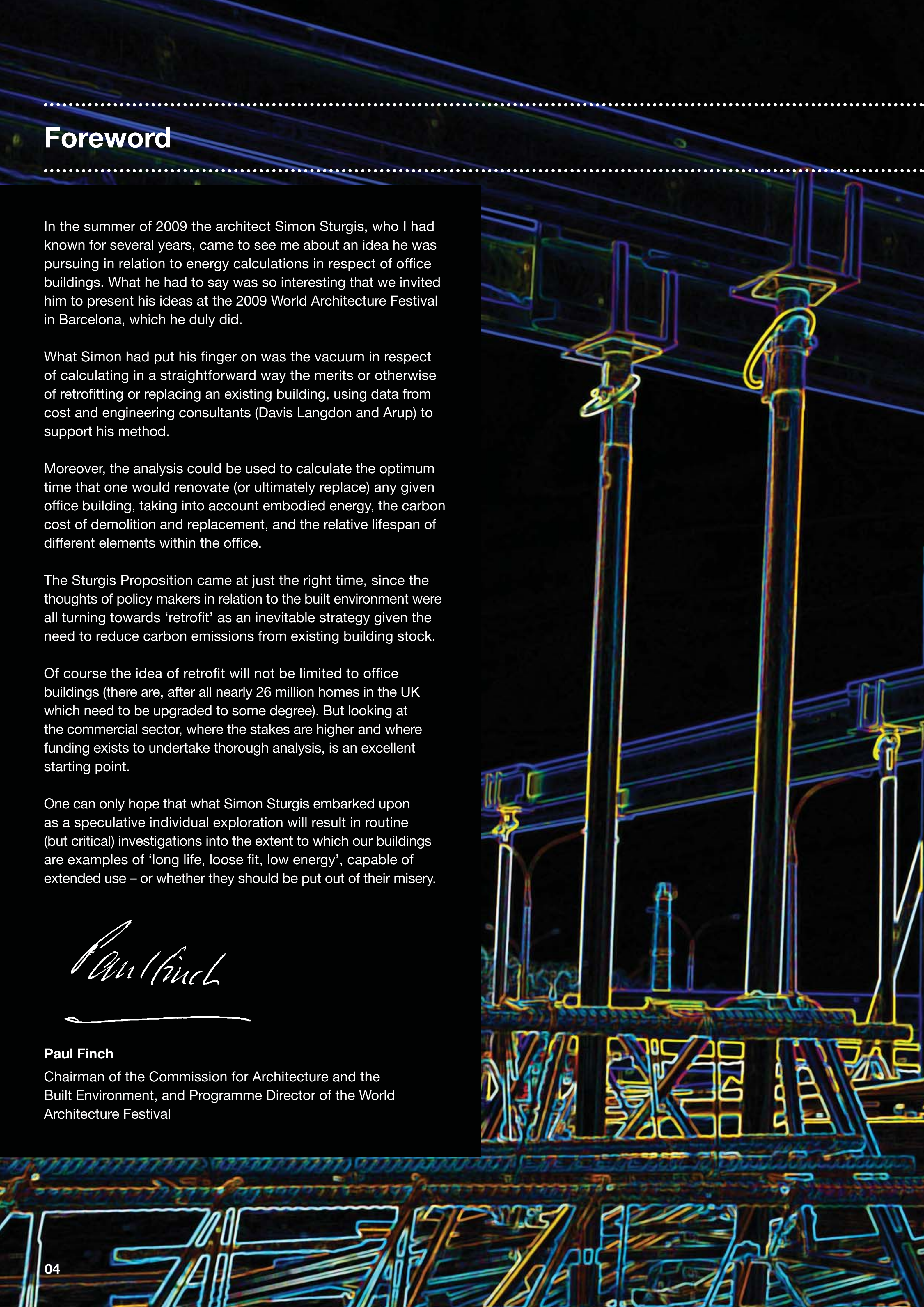

Foreword

In the summer of 2009 the architect Simon Sturgis, who I had known for several years, came to see me about an idea he was pursuing in relation to energy calculations in respect of office buildings. What he had to say was so interesting that we invited him to present his ideas at the 2009 World Architecture Festival in Barcelona, which he duly did.

What Simon had put his finger on was the vacuum in respect of calculating in a straightforward way the merits or otherwise of retrofitting or replacing an existing building, using data from cost and engineering consultants (Davis Langdon and Arup) to support his method.

Moreover, the analysis could be used to calculate the optimum time that one would renovate (or ultimately replace) any given office building, taking into account embodied energy, the carbon cost of demolition and replacement, and the relative lifespan of different elements within the office.

The Sturgis Proposition came at just the right time, since the thoughts of policy makers in relation to the built environment were all turning towards ‘retrofit’ as an inevitable strategy given the need to reduce carbon emissions from existing building stock.

Of course the idea of retrofit will not be limited to office buildings (there are, after all nearly 26 million homes in the UK which need to be upgraded to some degree). But looking at the commercial sector, where the stakes are higher and where funding exists to undertake thorough analysis, is an excellent starting point.

One can only hope that what Simon Sturgis embarked upon as a speculative individual exploration will result in routine (but critical) investigations into the extent to which our buildings are examples of ‘long life, loose fit, low energy’, capable of extended use – or whether they should be put out of their misery.

Paul Finch

Paul Finch

Chairman of the Commission for Architecture and the Built Environment, and Programme Director of the World Architecture Festival

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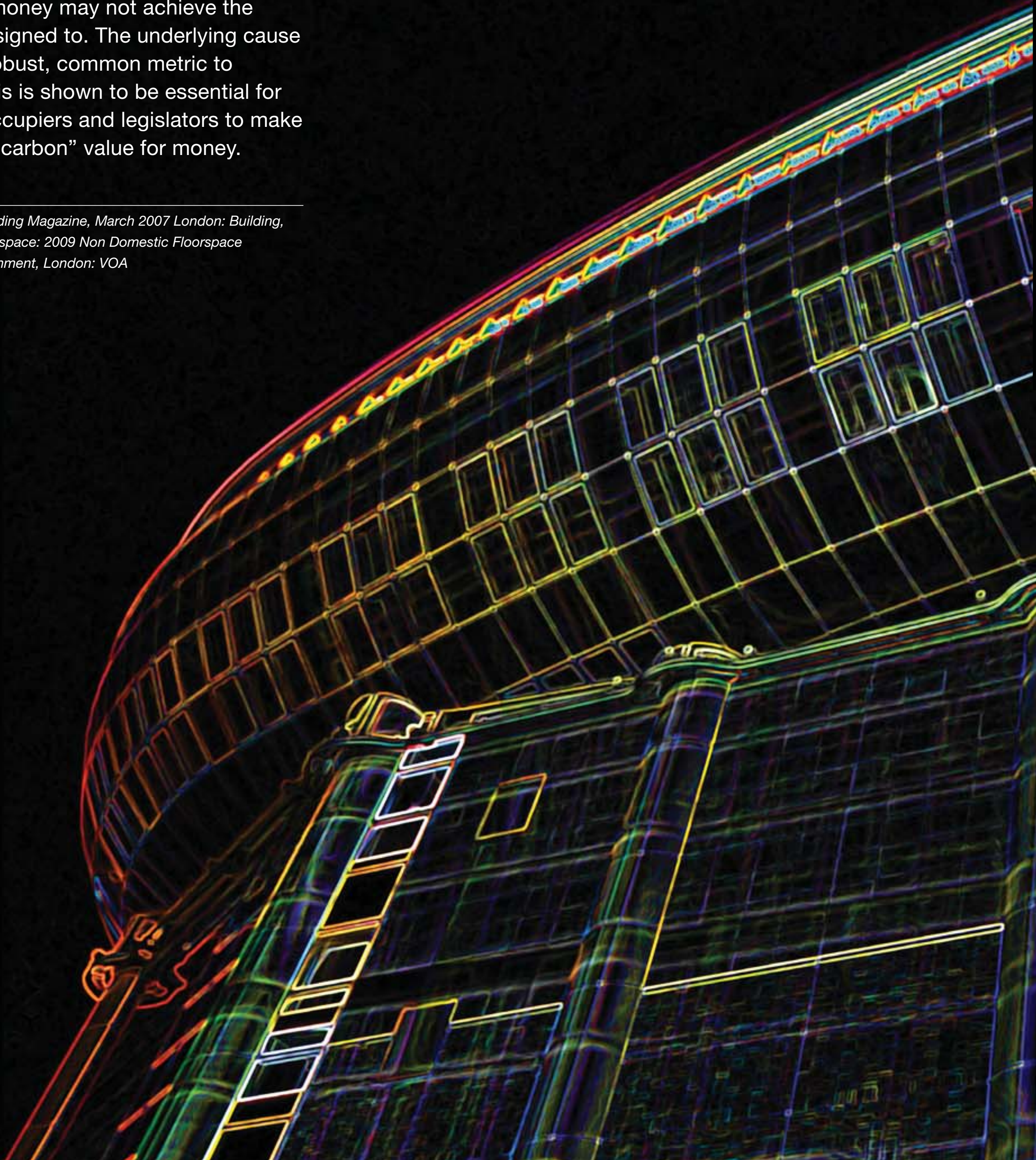
Key findings

THIS RESEARCH PAPER examines the issues associated with quantifying the whole life carbon dioxide emissions of buildings. It does this in the context of UK construction legislation and practice, which currently only calls for the partial inclusion of the sources of CO_2 generated by buildings specifically operational carbon use. The significant amounts of carbon used to make and maintain a building are ignored. Also disregarded is the interrelationship between embodied and operational carbon usage.

This paper demonstrates that many significant problems arise as a result of this definition, including the misallocation of environmental and financial resources. The seriousness of this situation is illustrated by the estimated £2.7 billion construction cost increases that UK commercial developers will be facing every year to comply with CO_2 reduction policies come 2019[1]. We identify that much of this money may not achieve the environmental goals it was designed to. The underlying cause of this failure is the lack of a robust, common metric to measure whole life carbon. This is shown to be essential for building owners, designers, occupiers and legislators to make informed choices and deliver "carbon" value for money.

This research proposes a solution to correct this problem, through the use of a new, simple carbon metric known as Carbon Profiling which quantifies all sources of emissions associated with buildings. Carbon Profiling links operational and embodied carbon usage so that they can be considered together. Crucially it evaluates the impacts of time and of when the emissions actually take place. This enables efficient resource allocation decisions to be made, and reduces the regulatory burden of cost increases to developers and UK occupiers. In addition, we finally discuss some of the broader issues that need to be addressed if we really want to ensure that we are creating a low carbon built environment for ourselves and future generations.



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[1] *Miller V. 2007 High Price of Zero Carbon, Building Magazine, March 2007 London: Building, UK Government Live Tables:Total Offices Floorspace: 2009 Non Domestic Floorspace Department for Communities and Local Government, London: VOA*

Glossary of terms

BCO. British Council of Offices

BER. Building Emission Rate

BREEAM. Building Research Establishment Environmental Assessment Method

Carbon emissions. This relates to the basket of greenhouse gases that give rise to global warming and that are expressed in equivalent units of CO_2

DEC. Display Energy Certificate. This shows the operational energy usage of a building, and is based on the energy consumption of the building as recorded by gas, electricity and other meters. The DEC should be clearly displayed at all times and clearly visible to the public. DECs are only required for buildings with a total useful floor area over 1,000m 2 that are occupied by a public authority and institution providing a public service to a large number of persons. They are valid for one year, and the requirement for Display Energy Certificates came into effect on 1 October 2008

ECE. Embodied carbon efficiency, representing the annualized carbon emissions rate associated with an entire major building component system

Embodied carbon. Carbon dioxide emissions that are generated from the formation of buildings, their refurbishment and subsequent maintenance.

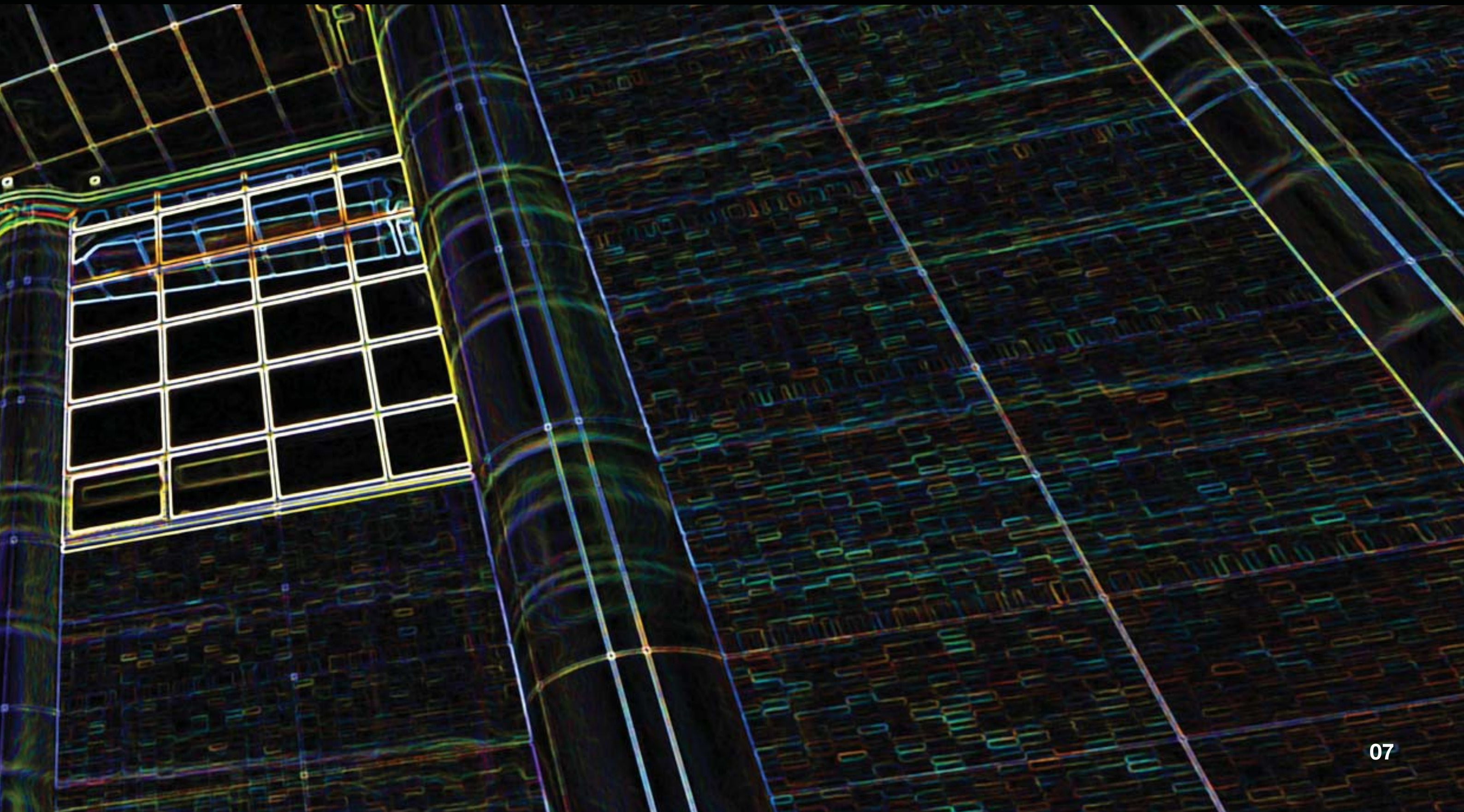
EPC. Energy Performance Certificates. An EPC is required for all homes whenever built, rented or sold. The certificate provides an A-G rating, and is produced using standard methods and assumptions about operational energy

Green Star. An environmental rating system administered by the Green Building Council Australia

LEED. Leadership in Environmental Energy and Design. LEED is a green building certification system, providing third-party verification that a building or community was designed and built using strategies aimed at improving performance across a range of metrics including: energy savings, water efficiency, carbon dioxide emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts

Operational carbon. Carbon dioxide emissions that are generated as the result of occupiers' day to day activities

Whole Life Carbon. The total amount of carbon dioxide emissions generated by a building over its life, including its formation and use.



Introduction

OVER THE PAST 40 YEARS improving the energy efficiency of buildings has been a growing concern for the property industry. This was initially in response to the oil embargos in the mid 1970s which led to the creation of minimum standards for the efficiency of building components. Today, however, energy efficiency targets are being driven by the need to reduce greenhouse gas (GHG) emissions in the whole economy. Within the next 10 years the UK is mandated to achieve a 20% reduction of greenhouse gas emissions over current levels, in response to our Kyoto commitments (figure 1). In the context of buildings, the scale of this challenge is quite considerable as identified in the research of Danny Harvey and others[2] that buildings were responsible for 7.85 gigatonnes (Gt) of carbon dioxide (CO_2) emissions in 2002, equivalent to 33% of the global total of energy-related emissions.

This step change in motivation behind energy efficiency measures has left various conflicting legacies in the legislation and in the metrics used to drive forward and define these targets. For example, the embodied carbon used to create a building may be as high as 62% of its total whole life emissions for some building types, as researched by Thomas Lane[3]. However this is still left unaccounted for in the building control approval process (Part L), and in other forms of measurement (e.g. BREEAM, EPCs, DECs etc) although operational i.e. in-use, emissions are measured and regulated.

This partial measurement of building emissions is fundamentally misleading, as it only provides half the picture when making CO_2 related design decisions. In addition it also ignores the link between the carbon emissions used to make a building and its energy efficiency once it is up and running. It is contended that the problem is a consequence of there being no common metric to evaluate all emissions generated by buildings with respect to time i.e. a measure of the efficiency of each item of fabric and services that provides benefits to occupiers, through the provision of, for instance, lighting, shelter, warmth, air quality, privacy and security.

This lack of a descriptive metric describing the carbon efficiency of a building gives rise to many common problems that building designers and occupiers face, which are currently left unanswered, such as:

- Is it better to demolish an old building that represents a large embodied carbon resource but is carbon inefficient, and replace it with a new highly efficient building? What is the CO_2 value of part retention allied to component recycling?

- Do the proposed renewables or protection measures for a given project generate real "net" benefits once the embodied carbon used to make them is factored in?

- What overall whole life CO_2 performance does Building A have when compared to Building B? Which building is more efficient overall, and what is the comparative efficiency of the space in each of these?

- Is it better to use high thermal mass to reduce a building's operational emissions even though more embodied carbon emissions are being generated through this choice?

- How is it possible to carry out and assess "green tendering and procurement" in the light of carbon emissions arising from construction?

- What is the residual embodied carbon benefit of an existing structure or component?

- How is it possible to generate carbon credits on building projects from "additional" emission reductions?

- Is the money spent on reducing construction carbon emissions yielding the greatest possible emission reductions on this project?

> **The embodied carbon used to create a building may be as high as 62% of its total whole life emissions**

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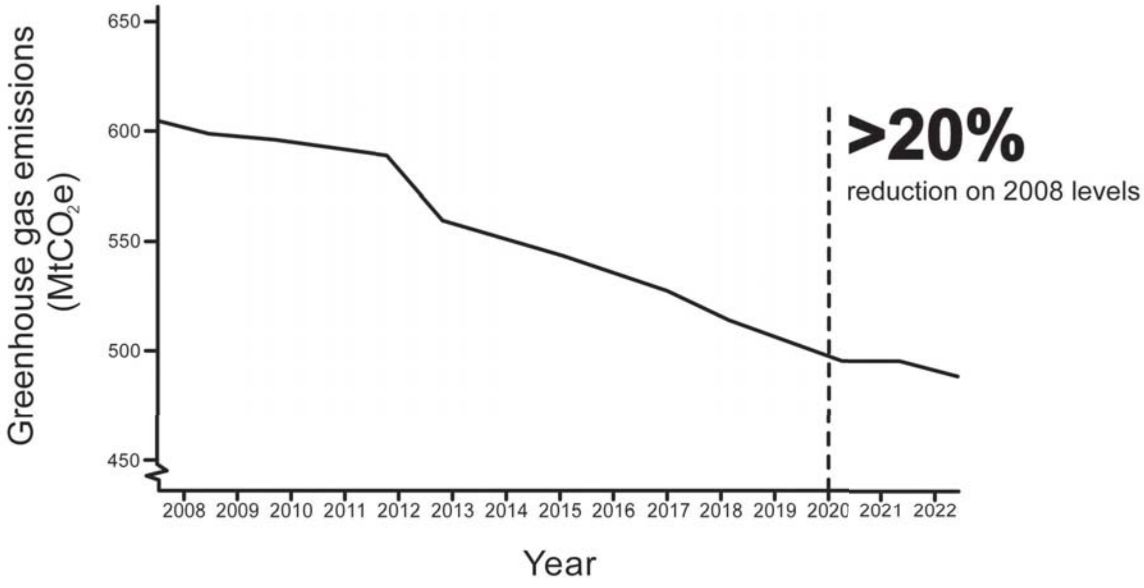
[2] *Harvey, L.D.D., et. al., 2007. Mitigating CO_2 emissions from energy use in the world's buildings. Building Research and Information, 35:4, 379-398. London: Routledge.*

[3] *Lane, T., 2007. Our Dark Materials. Building Magazine, 2007, Issue 45, London: Building*

Figure 1 UK emission reduction timeline



Source: Department of Energy and Climate Change

Understanding these relationships fully will become more important as the UK moves towards achieving its Kyoto Protocol Commitments as set out through the UK government's Low Carbon Transition Plan. The UK National Audit Office[4] identifies these concerns in respect of the government estate where establishing methods which meet environmental targets at minimal cost has been seen as a priority.

Current legislation in the construction sector still, however, excludes a consideration of embodied carbon emissions, and concentrates solely on operational carbon emissions targets. These targets currently stand at achieving zero operational emission for all domestic buildings after 2016 and zero operational emissions for all new non-domestic buildings after 2019, as set out by CLG and the UK Green Building Council[5]. If this legislation is not amended, these policies would give rise to the unusual situation by these dates whereby all emissions generated by buildings will result from the embodied carbon used to build and maintain them, with no regulation in place to ensure this is done without causing excessive negative environmental impacts. This trend was identified by Guy Battle and reported by Thomas Lane, who noted the recent changes in the ratio between operational and embodied carbon emissions, which was 80:20 and is now becoming closer to 60:40 for an average building.

Work by David Weight and Simon Rawlinson[6] in 2007 further builds on this observation by considering the impact that current carbon emissions will have on future generations, recognising the increasing role embodied carbon will play in assessing this.

It should also be of concern that measures employed to meet these operational reduction targets may well have the consequence of increasing embodied emissions. This would be counterproductive but legislatively correct.

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[4] *NAO (National Audit Office), 2007. Building For the future: Sustainable Construction and refurbishment of the Government Estate 2007. London: The Stationary Office*

[5] *Department for Communities and Local Government, UK Green Building Council, 2007. Report on carbon reductions in new non-domestic buildings. London: Queens Printer.*

[6] *Weight, D., Rawlinson, S., 2007. Sustainability Embodied Carbon. Building Magazine, 2007, Issue 41, London: Building*

Carbon emissions associated with buildings

TO DEVELOP A PICTURE of the carbon emissions of buildings it may help to introduce some categories of where carbon emissions may be generated from. Work by others such as Catarina Thormark[6] in 2002 on embodied carbon and Smith[7] in 2008 with respect to whole lifecycle footprinting, as well as the definitions provided with the life cycle assessment standards (ISO14040: 2006 –ISO 14044: 2006) and life cycle greenhouse gas emission of goods and services (BS PAS 2050:2008) demonstrate how effectively this territory has been mapped out. Essentially, they may be summarised as follows:

Inherent Resources
Carbon resource attached to an existing site or building

Additive Emissions
Carbon resources used to transform a site or building into the new or reformed asset

Operating Emissions
Carbon emissions arising from the use of a building

Maintenance Emissions
Carbon emissions arising from keeping a building in good repair

End of Life Emissions
Carbon emissions from eventual disassembly or demolition

These categories may further be simplified into two basic groups as shown by figure 2:

Operational Carbon Emissions – arising from using the built asset

Embodied Carbon Emissions – arising from creating, maintaining and demolishing the built asset.

On the following page, figure 3 provides an indicative breakdown of the different sources of these emissions from a central London office building.

Figure 2 What are operational and embodied CO_2 emissions

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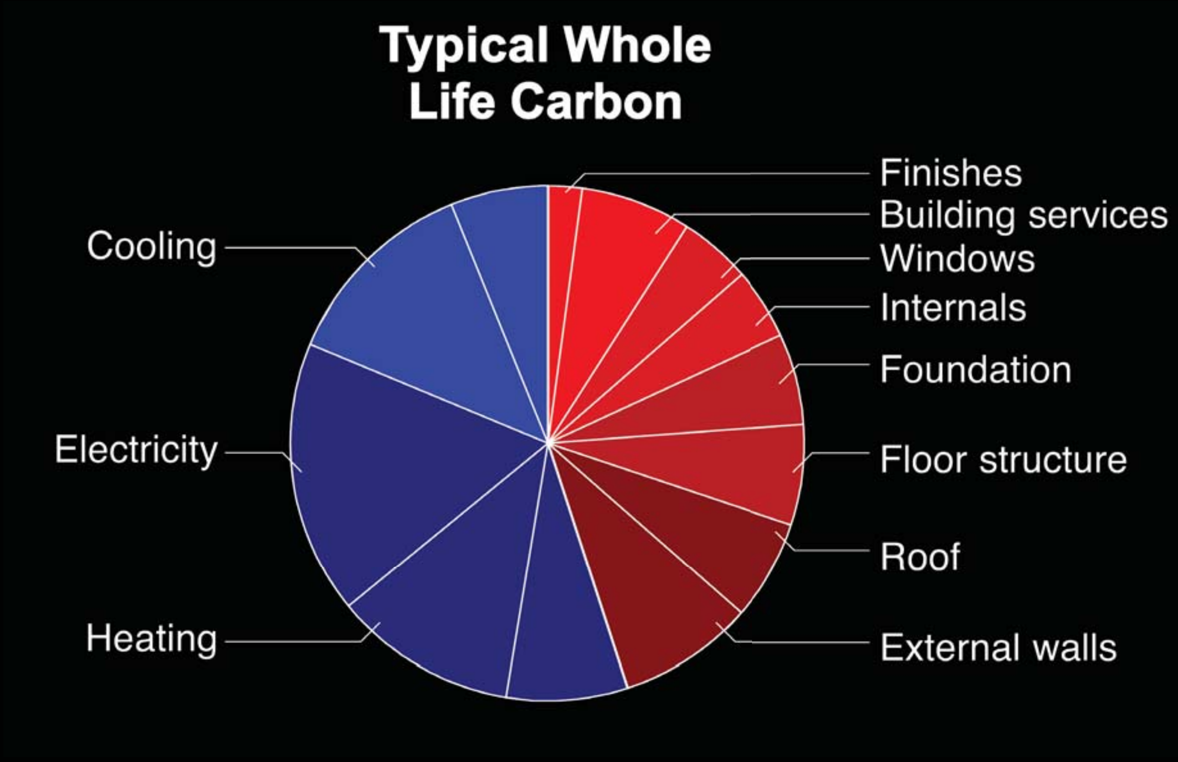
[6] *Thormark, C., 2001. A low energy building in a life cycle – its embodied energy, energy need for operation and recycling potential, Oxford: Elsevier.*

[7] *Smith, B.P., 2008 Whole-life carbon footprinting. [Article], The Structural Engineer, 18th March 2008. London: iStructE.*

Figure 3 Typical whole life carbon emissions from an office building



Source: Sturgis Associates LLP Indicative Whole Life Carbon Emissions

What are Operational Carbon Emissions?

These are the emissions that are generated through the activities of the occupier of the building, i.e. lighting, heating, cooling, electricity for power etc. At present considerable attention is given by both legislation and the property industry to the reduction of these emissions. This is typically achieved by reducing the requirements of a building through the use of insulation, shading, natural ventilation and other passive measures. These can then be augmented by either more efficient modern systems for heating, cooling etc, or by the use of renewable energy sources, e.g. wind turbines, solar power etc.

The measurement of the operational carbon emissions of buildings is achieved by various standard methods such as EPCs and DECs.

What are Embodied Carbon Emissions?

These are the emissions that come about through the construction, maintenance, refurbishment and alteration of a building, including those that arise from the extraction and manufacture of building materials, their transport, and their assembly on site. Also included are any emissions that come about as a result of the demolition and removal of any existing structures or components. Much work has been done across the industry to quantify the embodied carbon in construction by many consultancies such as Davis Langdon, dCarbon8, etc. However there is no commonly recognised method of simultaneously analysing both the embodied and operational carbon emissions with respect to any one time period.

Carbon emissions associated with buildings

Is energy a better measure than carbon emissions?

As we will explain in more detail further in the paper, CO_2e measures may be a more uncertain measurement in some situations where material processes are based on estimates when sources are not known, but we believe it is important to link the motivation for measurement to the choice of units used. This will also incentivise better reporting of these figures as demand for information will grow.

This does not mean reducing energy usage is not important, but the key point is that reducing carbon intensive energy usage should be viewed as more important. With regard to dealing with the environmental challenge of global warming, carbon measured as CO_2e is a much better proxy than energy measured as KJ.

The use of CO_2e (carbon dioxide equivalent) additionally allows for the relative weightings of damage that the different greenhouse gasses cause, e.g. 1 tonne of CO_2e is, in terms of its greenhouse gas potential, equivalent to:

1 tonne of carbon dioxide
21 tonnes of methane
290 tonnes of nitrous oxide
140–11,700 tonnes of halocarbons (HFC)
22,000 tonnes of sulphur hexafluoride

It should be noted that these figures are calculated on two variables: the gasses' potential to absorb infrared radiation and its atmospheric lifetime. The first of these is much more certain than the second which is why figures for global warming potential may often be shown to have a wider range of impacts the longer they last in the atmosphere.

Picking up on the relative impacts is important, as the manufacturing of some building materials (e.g. insulants) may give rise to high levels of some greenhouse gasses whilst not requiring much energy to produce. In such instances not examining the impact through CO_2e emissions will bias any comparable analysis undertaken.

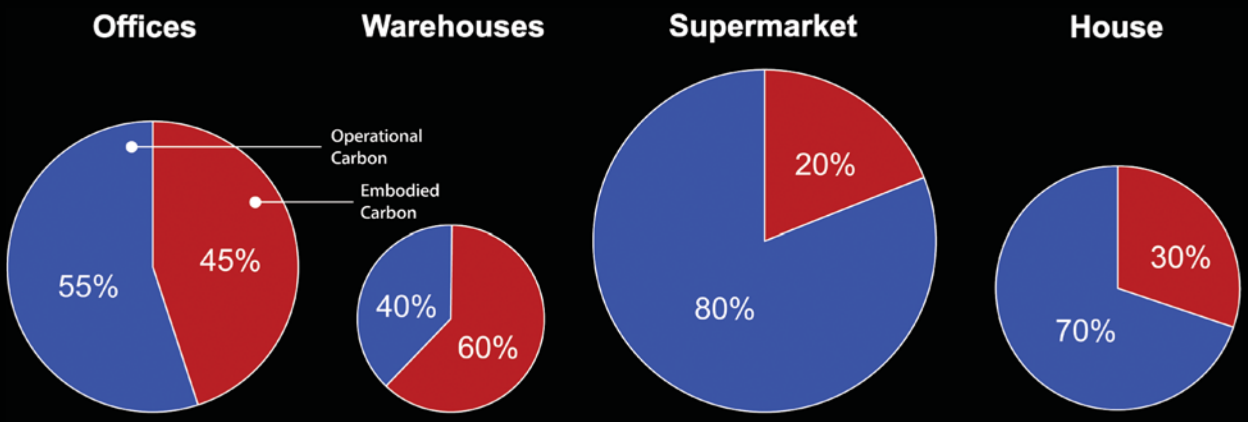
What is the link between operational and embodied carbon emissions?

In the case of office buildings, currently some 40–50% of the whole life carbon costs of a typical new development will be due to embodied carbon emissions. This proportion is set to increase due to legislation requiring operational carbon emissions to be reduced to zero by 2019. There is, however, a danger that this pressure will have the unintended consequence of adversely affecting embodied emissions, by requiring the use of increasingly carbon-intensive solutions, the closer we get to zero operational carbon emissions. Understanding the relationship between the underlying embodied and the operational carbon emissions is essential when allocating any resources to reducing emissions overall, as it is crucial to ensure that the physical measures taken to reduce operational carbon usage use less carbon than they save. In addition, from a purely financial point of view, reducing embodied emissions through design can be more effective than reducing operational emissions.

The impact of different building types

Understanding the whole life carbon picture of individual buildings is also essential from the perspective of setting targets. Different types of buildings give rise to different relative embodied/operational carbon ratios (see figure 4). This is well described by Thomas Lane in the context of different types of warehouses: the operational carbon emissions of a refrigerated storage warehouse will be a significantly higher ratio of total emissions, at about 90%, compared with a warehouse for dry goods, where the ratio will be about 10%. Likewise, offices have relatively high embodied carbon footprints when compared to residential buildings.

Figure 4 Typical different Whole Life Carbon splits for different types of buildings



Source: Sturgis Associates LLP Indicative Whole Life Carbon Emissions

Figure 5 Typical different Whole Life Carbon splits for different types of buildings 10 years time

Source: Sturgis Associates LLP Indicative Whole Life Carbon Emissions

The differences between uses become crucial when we are considering the level of emission reductions we want to achieve, and the most appropriate approach in order to achieve them. Over the coming 7–10 years, existing and forthcoming legislation will be aiming to reduce operational carbon emissions down to zero. Therefore the remaining carbon emissions associated with any building will be solely the embodied emissions. These indicative changes are shown in figure 5.

By comparing these two diagrams, it can be seen that for some building types this will be more of a challenge than for others. We believe this to be inefficient as the burden could be reduced by legislating for embodied carbon as well, making it possible for designers to achieve the overall carbon emission reduction targets in the most cost effective way.

A second point is that by targeting both embodied and operational carbon emissions for reduction together, rather than operational alone, a greater overall reduction should be achievable for a given cost in the long run.

> **“The differences between uses become crucial when we are considering the level of emission reductions we want to achieve**

Carbon emissions associated with buildings

Time, lifespan and emissions

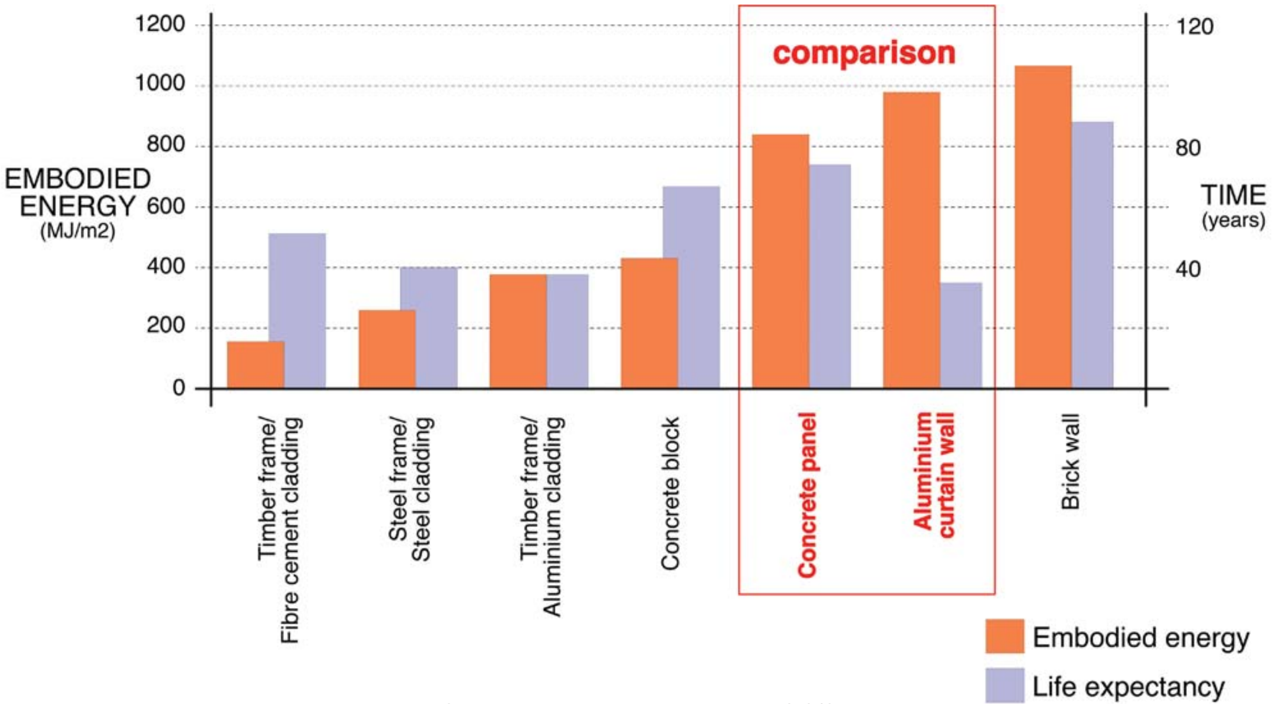
Evaluating emissions requires an understanding of how the period in time at which they are generated relates to when the benefit is derived. Turning on a light bulb is quite easy to conceptualize – the emissions are being generated "live" in the moment of use for the user turning on the switch. However the emissions generated by manufacturing a carpet may have occurred perhaps months before its use and this expenditure may also then be shared over the seven or so years of its life.

Another point to note regarding the impact of time is that the built environment around us represents an existing resource of spent carbon. Indeed, part of the fact that global warming is currently happening is down to its existence. With this in mind decisions to destroy any of this potentially reusable resource should be measured against the benefits of any new proposals and how long they in turn may last.

Finally, understanding the lifespan of building components or systems is crucial to the understanding of their embodied carbon efficiency. For example, in comparing two cladding systems, concrete and aluminium, the work of Janis Birkland[8] in 2002 showed that both had similar embodied energy investments (see figure 6), but that the anticipated lifespans were very different. When examined using BCIS[9] data, the concrete system has roughly twice the life of the aluminium system. In this example it could therefore be said that the concrete system had twice the embodied energy efficiency of the aluminium. This sort of information is vital to the designer who is selecting components for their durability, and who needs to be able to carry out a comparative carbon analysis of their relative efficiency.

Raymond Cole and Paul Kernan[10] made a similar observation to this, by looking at recurring embodied energy and found that by the time a typical office building is 50 years old, 144% of the initial embodied energy will have been spent again through maintenance and replacement of fabric. Crucially, they identify the cladding finishes and services as the biggest component of these recurring carbon emissions, and their component lifespans being the biggest coefficient in determining the magnitude of these recurring emissions.

Figure 6 Lifespan and Embodied Energy of different Cladding Systems



Energy values from Janis Birkland Design for Sustainability 2002, Lifespan data BCIS/Sturgis

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[8] *Birkland, J., 2002. Design for Sustainability: A Sourcebook of Integrated, Eco- Logical Solutions. Sheffield: Earthscan Publications.*

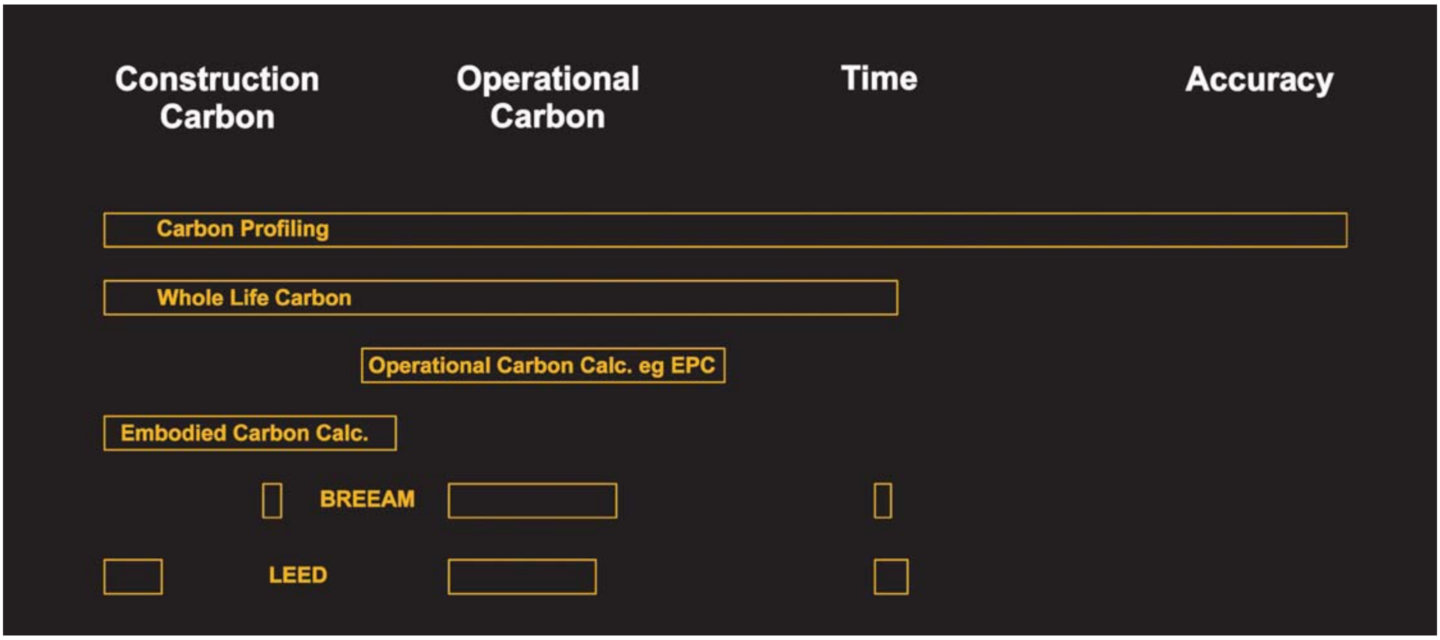
[9] *BCIS, 2006. Life Expectancy of Building Components. 2nd ed. London: Connelly-Manton (Printing) Ltd.*

[10] *Cole, R. J., Kernan, P. C., 1996. Life-Cycle Energy Use in Office Buildings. Building and Environment, vol. 31, no. 4. Oxford: Elsevier.*

Alternative metrics

TO DATE MUCH WORK has been done by others to define sustainability and what is meant by a 'green' building. This in itself is a very large topic covering a whole range of activities from encouraging biodiversity through to recycling waste paper. Many of these measures also have an impact on carbon dioxide emissions, and so warrant a mention in the context of this report. An overview is shown in figure 7. It is not the authors' intention to highlight these various definitions as bad or good examples, as each has benefits for particular applications. But in the context of providing an overall carbon efficiency standard, it is the authors' view that they do have some serious shortcomings, which justify the introduction of a new technique, concentrating solely on this particular and critical issue. In the next section this new technique – Carbon Profiling – will be described in more detail.

Figure 7 Overview of different types of metrics



Alternative metrics

Whole Life Cycle Carbon Footprint

This method is based on evaluating all of the carbon emissions that are anticipated to take place over the life of a building. It has the advantage of considering both embodied and operational emissions at the same time but has the disadvantage of having to make some quite significant assumptions about the carbon intensities of future fuel use. Whole Life Cycle also fails to make explicit where the responsibility for those emissions may lie, i.e. the developer or the occupant, or the proportion of this footprint that is attributable to the use of a particular piece of space.

Operational Carbon Calculators

Examples of these are the Energy Performance Certificates (EPCs) or Display Energy Certificates (DECs) using models such as sBEM, SAP and LESTER. Operational Carbon relates to the carbon emissions generated by the use of a building, but fails to consider the relationship with the embodied emissions. For instance, when a designer is deciding upon the optimum thickness of insulation to specify, with an operational carbon calculator the thicker piece will always be shown to achieve greater carbon emission reductions. These figures are, however, gross reductions. It is the net figure, that incorporates the extra embodied carbon emissions arising from the manufacture of the insulant, that needs to be analysed in conjunction with the savings, to discover the true optimum thickness. For these reasons operational carbon calculators can be misleading and can sometimes give rise to over-specification.

Embodied Carbon Calculators

There are many of these in existence and they have contributed greatly to raising awareness of the issues associated with carbon emissions from construction. However they are also subject to the same problems as the operational carbon methods, in that they only give a partial picture of what is happening without giving any insight into how the reduction of one set of emissions affects the other.

BREEAM / Code for Sustainable Homes / LEED / Green Star

All these assessment methods are very useful in addressing the wider range of sustainability issues for the built environment, but they deal only partially with the analysis of embodied carbon and operational carbon emissions. For example the placing of bat and bird boxes on a building may gain more points under some assessment procedures than retaining the structural frame of a building, which may embody many tens of thousands of tonnes of carbon.

To summarise, only whole life footprinting is capable of analysing both embodied and operational emissions together. This, it is contended, is essential as the two issues are inherently interlinked. For instance building a wind turbine to reduce operational emissions will also give rise to embodied carbon emissions from building its substantial foundations, the making of the generators and the blades and the transport of the turbine to site. Understanding the costs as well as the savings is essential in developing a balanced carbon cost/benefit analysis to help make the correct recommendations on a project. Failure to take the embodied carbon costs into account can lead to over-specification and wasteful use of both carbon and financial resources and in some instances give rise more carbon emissions being generated than are genuinely saved.

That said, whole life footprinting does have a number of shortcomings; it lacks any degree of accountability and any durability analysis, as it “assumes” all the resource allocation decisions that will take place not only today but also over the extent of a building’s life. All of the built fabric is assumed to last a fixed period, 60 years, which is both general and inaccurate. Again, as suggested by Cole and Kernan, this is a simplification. This over-estimation of fabric life also typically has the effect of reducing the relative importance of embodied carbon emissions in comparison with operational emissions. Whole life footprinting’s other failing is that it offers no solution to the problem of what happens if these assumptions are not borne out in reality and who should pay the price.

The other metrics have many broader sustainability benefits but they should be used with caution if simply used for evaluating carbon emissions. So the important question becomes how effective is whole life footprinting?

It is contended that a metric should be based in “real time” describing the carbon efficiency of a space at any given moment, without having to rely on discounting future emissions, or making assumptions about how much carbon a kW of electricity may create a long time in future. This helps remove the uncertainty and a lack of flexibility inherent in whole life footprinting.

In particular, it does not provide clear evidence as to how to make efficient allocations of financial and carbon resources, at the acquisition and design stage, nor does it inform occupiers how different buildings in embodied and operational terms perform, or help clarify yearly emission reporting to occupiers.

It is contended that a metric should be based in “real time” describing the carbon efficiency of a space at any given moment, without having to rely on discounting future emissions, or making assumptions about how much carbon a kW of electricity may create a long time in future. This introduces uncertainty and a lack of flexibility as it makes current decisions void if events differ from those that are currently being assumed.

Any metric should also be balanced, in that it should reflect the decisions that have actually been made or are actively being modeled, incorporating any opportunity costs of emissions destroyed and should not include any allowances for what might happen at the end of a building’s life, as again this introduces uncertainty and lacks accountability.

Whole life carbon footprinting may also give rise to some rather perverse effects such as less efficient plant being installed in the future being considered as equal to high efficiency plant being installed today, This rises many complex questions about how we judge future generations’ well-being in relation to our own.

Finally the output of a whole life carbon footprint is complex to interpret and make use of in any one given moment in time. It proves difficult to use to allocate responsibilities to the different parties who are giving rise to emissions, as generally, over half the emissions being included have not as yet actually been put into the atmosphere.

Carbon Profiling – Methodology

CONTROLLING AND REDUCING the use of CO_2 is now the critical issue of our time. However, there is no simple recognised method of quantifying the carbon used to both construct and use a building over time. In response to the above lack of a model that links operational carbon emissions and embodied carbon emissions over time, the authors have then set out to create one – Carbon Profiling. In the following section it will be described how it works and its benefits will be outlined.

The basic objective of Carbon Profiling is to have a metric that is capable of analysing operational and embodied carbon emissions at the same time, and on the same unit basis (see figure 8).

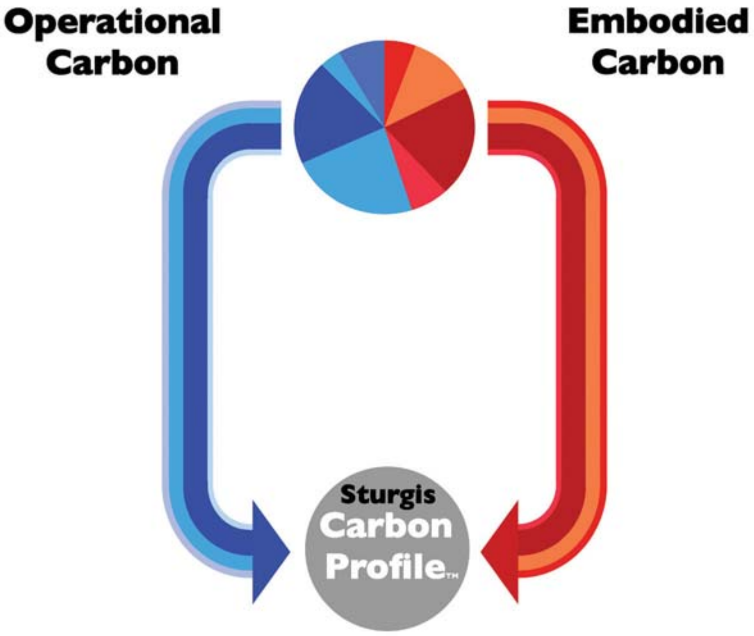
The outputs of Carbon Profiling provide a clear picture of what the annual emissions are associated with a given quantity of space of a building i.e. the carbon efficiency of a property. This allows it to be simple to comprehend, scalable within a building and makes comparisons between buildings easy.

The Carbon Profile is essentially developed in two parts: one part making use of the existing industry standard, the Building Emission Rate (BER) and the other part being the Embodied Carbon Efficiency (ECE) which is a new model originally developed by Sturgis Associates for use in creating a Carbon Profile.

Some of the main challenges confronted in developing Carbon Profiling are that it should be able to:

- Aid/inform local development control policies and feed into the creation of carbon budgets for sites at the planning stage
- Help owners and developers describe the comparable 'carbon' value of different buildings in simple scalable terms
- Aid design teams and contractors to define the best mix of specifications and technologies employed to create low carbon buildings
- Quantify the carbon value of existing and refurbished buildings and enable a comparison with new build
- Demarcate between landlord and tenant carbon emissions in a building.

Figure 8 Overview of Carbon Profile



Carbon Profiling - Methodology

DEFINING THE BOUNDARIES of any whole life assessment is essential. For Carbon Profiling, these are defined as the 'Legal' Scope and the 'Physical' Scope.

'Legal' Scope

Carbon Profiling explains the whole life emissions solely of the building and does not seek to explain emissions arising from other activities, such as occupier travel or the types of non-permanent fixtures present in a building (see figure 9). The intention is to make a clear distinction, so that the Carbon Profile represents the carbon impact of the accommodation that the building provides. The rationale of this is to ensure that it can aid locational assessment by prospective occupants on a like for like basis. Where buildings are owned and – more likely – occupied by many different people, the profile is split along the lines of the legal incidence of responsibility of a property, so that a building owner's profile represents their legal responsibilities to the fabric as covered by statutory involvement through planning and Building Control legislation. The occupiers' profile therefore covers the areas they control, affect and are held legally responsible for.

At the design stage, as with Building Control Part L calculations, allocated levels of occupier carbon emissions will be made, e.g. for heating, lighting and cooling, but once the building is built, these will then become updated with real life data.

In separate multi-occupant buildings these allocated levels of occupier emissions will be devolved to the individual tenant areas once they take up occupation, and then real life figures can be substituted and imputed directly into their own individual Carbon Profiles.

Allocating levels of occupier emissions at the design stage will help prospective occupiers to simply compare different buildings on a like for like basis. The allocated levels will all be defined by their ability to deliver the same level of internal comfort and specification as required by Building Regulations. In addition these levels will also provide occupiers with some initial benchmarks for in-use efficiency.

'Practical' Scope

The 'Practical' Scope describes which items should be measured on the original site during the construction and use phases, and finally the beginning of the next lifecycle of the site. One of the key assumptions here is that of responsibility, i.e. the items to be measured should reflect the effects of one's actions and decisions. For example, if works involve destroying an embodied carbon resource or using low carbon technologies, both should be measured and logged into the profile as a negative or a positive entry.

A crucial aspect of this accountability, in that a Carbon Profile is not reduced by what "may" happen in the future, e.g. at the end of a building's life, if the building gets recycled or reused. The benefit of this is only reflected in the Carbon Profile when it actually happens, e.g. when sourcing components at the outset.

This non-inclusion of end of life recycling benefits is crucial to giving an accurate and balanced assessment of a building at the time of the assessment. Taking account of an event that has not or may not occur introduces a large amount of speculation into the data. This then poses a risk of double counting if the material, which is recycled, is then used on another building afterwards and its recycled discount is applied once again.

By only including the designed benefits that have been applied at the construction phase, designers are given an incentive to source lower carbon products, which in turn stimulates demand for recycled materials.

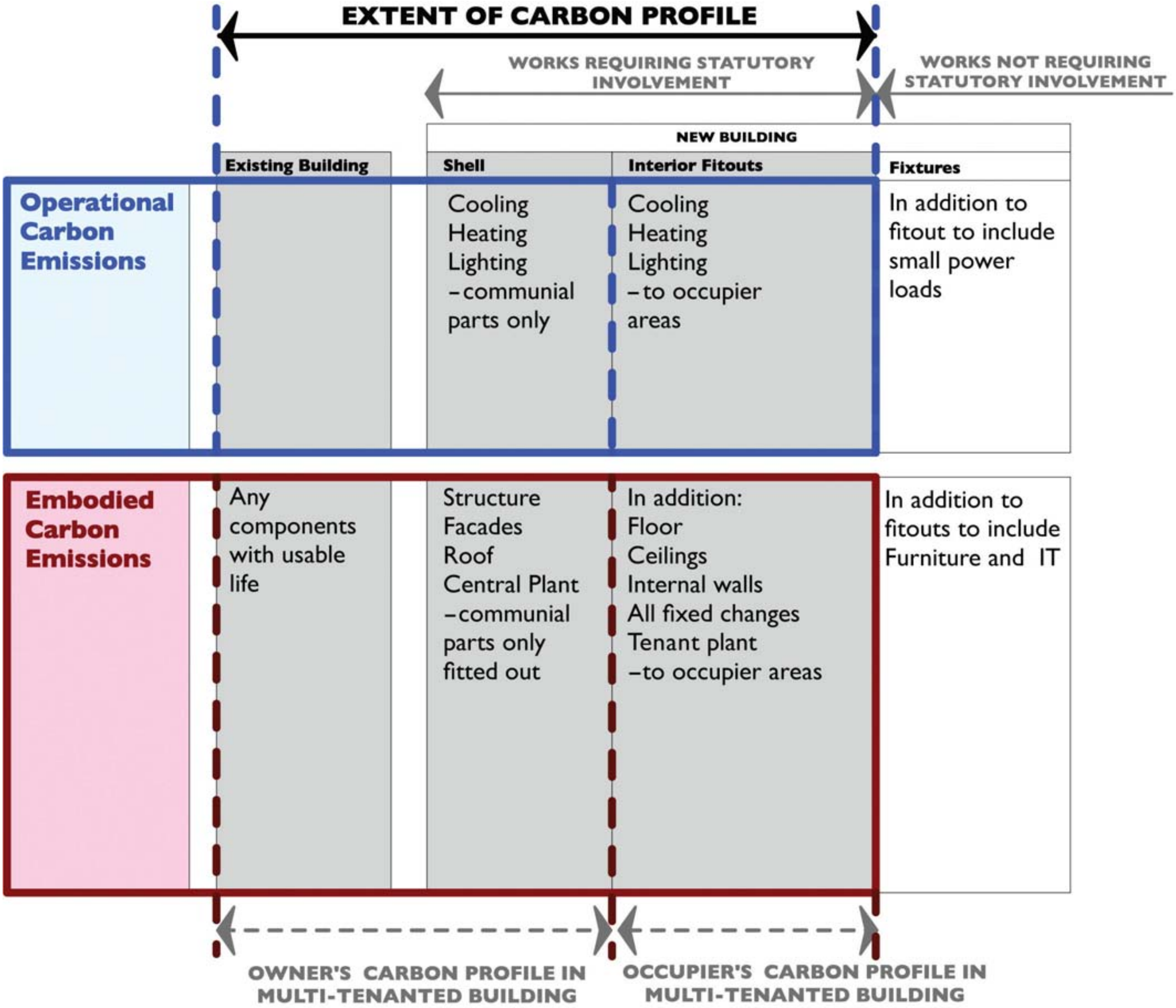
Reviewing the Carbon Profile at key events such as refurbishment, alteration and occupancy change reflects the responsibility for decisions that have occurred in a building's development, and are not purely speculation as to what future owners or occupiers may or may not do.

The 'Practical' Scope for each building is therefore as follows:

- Demolition and removal of existing site components
- Value of any resources destroyed
- Carbon emissions from the use of new material and the reprocessing of recycled material
- Transport of components
- Assembly of components (including plant, scaffolding etc
- Maintenance of components
- Carbon emissions from the operational use of the building.

Below is the scope diagram for an owner-occupied building's Carbon Profile:

Figure 9 Legal Scope



Carbon Profiling - Methodology

Calculation Methodology

This example of a Carbon Profile is carried out in the context of an office development utilizing sBEM modelling, and would require adjustment for residential (SAP) or other circumstances, as appropriate.

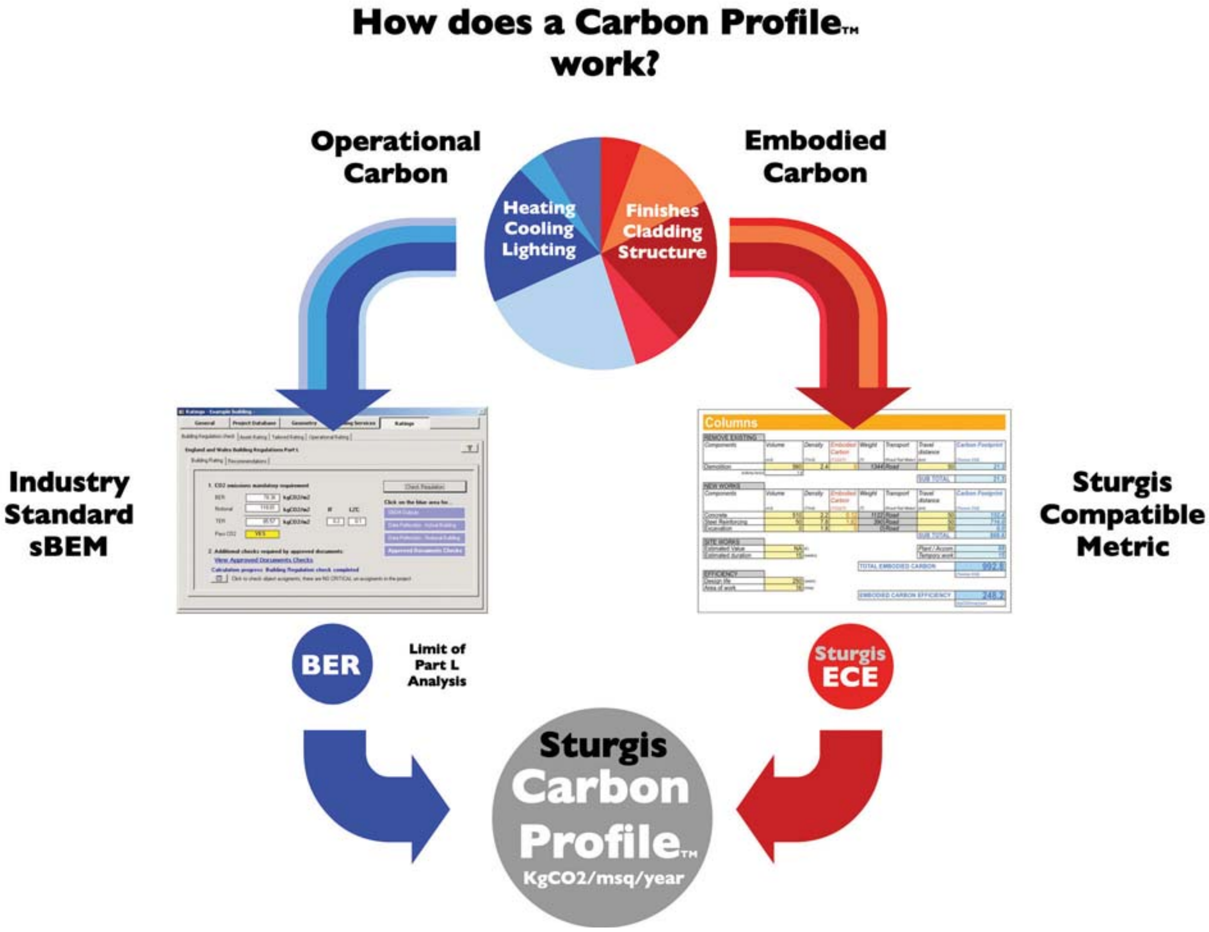
Deriving a Carbon Profile is a two-stage process – firstly, the calculation of the BER (Building Emission Rate) using sBEM to define the occupational emissions of the building, and secondly the calculation of the ECE (embodied carbon efficiency), which focuses on the embodied carbon in the built systems. These two results, which are individually important, can then be combined to give the Carbon Profile for the given building as shown in figure 10. Different buildings can therefore be compared for their overall carbon performance, by comparing their respective Carbon Profile results.

Given that sBEM is an existing industry methodology (for non-domestic buildings) it will not be reviewed here in great detail[11]. However ECE, as derived by Sturgis Associates, will be examined and critiqued over the following pages.

The ECE produces an annualized carbon emissions rate associated with an entire major building component system e.g. roofs, facades, structure, plant and fit out etc. This is calculated by using lifespan data from BCIS. These rates are then factored against their embodied carbon emissions, which take account of the forming of materials, their transport, and their assembly on site. Within any given system, it is necessary to establish the interdependencies between components and identify the weakest link. The weakest link will determine the anticipated lifespan of a given system and provide the time period against which the whole systems carbon expenditure will be evaluated (figure 11). The combination of all of these systems gives the total annual embodied carbon efficiency of a building, which is then converted into the ECE by division by the Net Internal Area (NIA). This now has the distinct advantage of being measured in KgCO$_2$/msq/year, which are the same units as the BER. This allows these two measures to be combined, giving the Carbon Profile of a building.

But how reliable are material lifespans as indicators of a building's realised life?

Figure 10 Calculations part of a Carbon Profile



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[11]*For further information on its use, see Communities and Local Government (2008), which is a good source of information for how this metric works.*

It may be argued that buildings rarely come to the end of their lives due to the failure of a specific component, causing their collapse. However, there is a clear relationship between the periodic appraisal of buildings as financial assets and the material lifespan of a building. Within each financial appraisal, future capital expenditures will be a feature – the closer these expenditures are to the present value, the less discounted they will become and the greater their impact on decision making. When the horizons to anticipated replacement are short they will reduce the opportunity costs associated with demolition and redevelopment. This effect is further magnified by the fact that the replacement of large systems, e.g. structure and cladding, require lump sum expenditures that often cannot be phased and may require the building to be vacated, further reducing the income cash flow from the asset.

In some circumstances, however, buildings may be demolished or components destroyed due to other reasons but here we believe it is right to identity this as a waste of resources and so take account of this loss as a "debit" in the next Carbon Profile for the space that is created as a results from this action.

Calculating the ECE

This requires five distinct stages of work:

Stage 1
Assess the embodied carbon value of the existing useable resources.

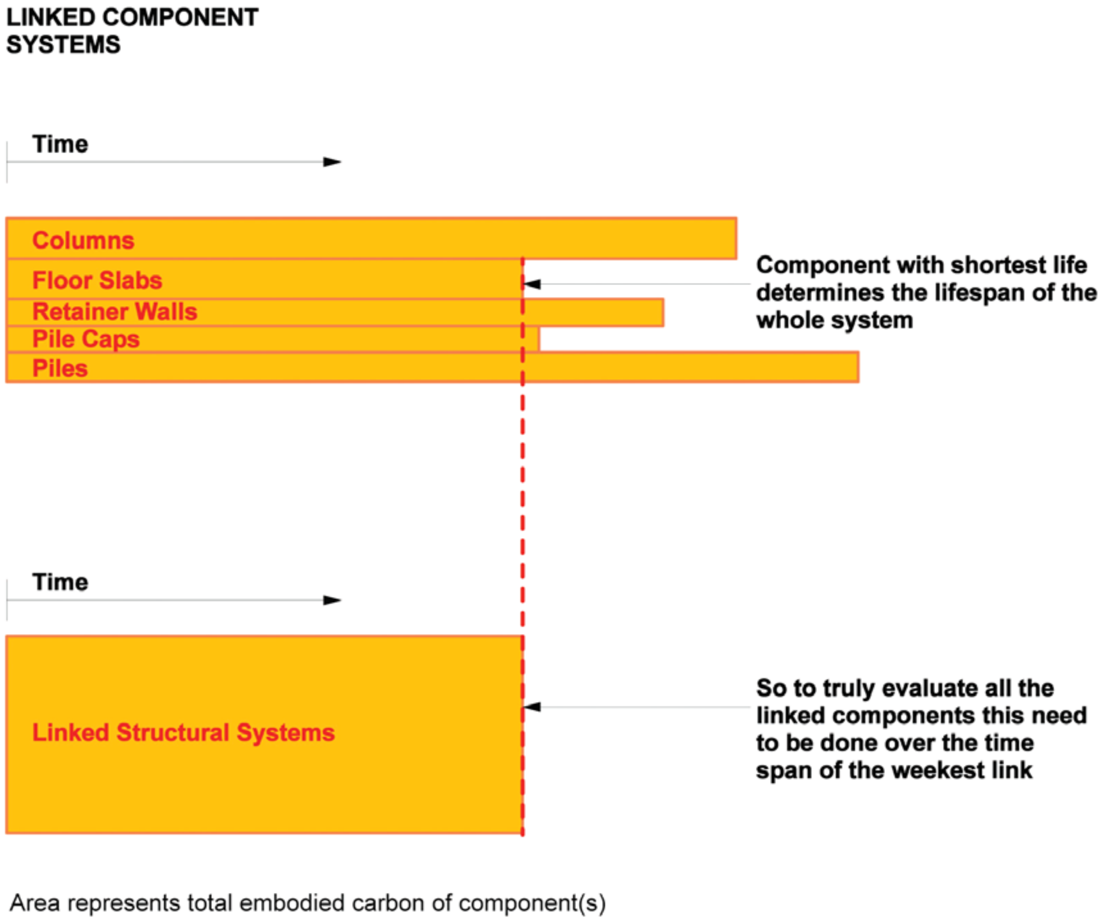
Stage 2
Assess the embodied carbon in the building components for each proposed system (or, if necessary, individual component).

Stage 3
Factor in the lifespan data for each.

Stage 4
Identify the weakest links in chains of components and redesign if necessary.

Stage 5
Combine the systems into the ECE. It should be noted that the calculation of the initial ECE is based on the best data available for any given design stage.

Figure 11 Evaluating linked components



Carbon Profiling - Methodology

Dealing with existing resources

This forms a key part of the assessment procedure. The basic principle is that any existing resources on site that are to be destroyed should be evaluated and included in the overall assessment.

So how do you decide the value of existing site resources? If a previous Carbon Profile has been compiled, this should provide the answer for this by referring back to the original lifespan estimates and embodied carbon amounts. From these it may be possible to pro rata the value of the existing resource remaining for any component.

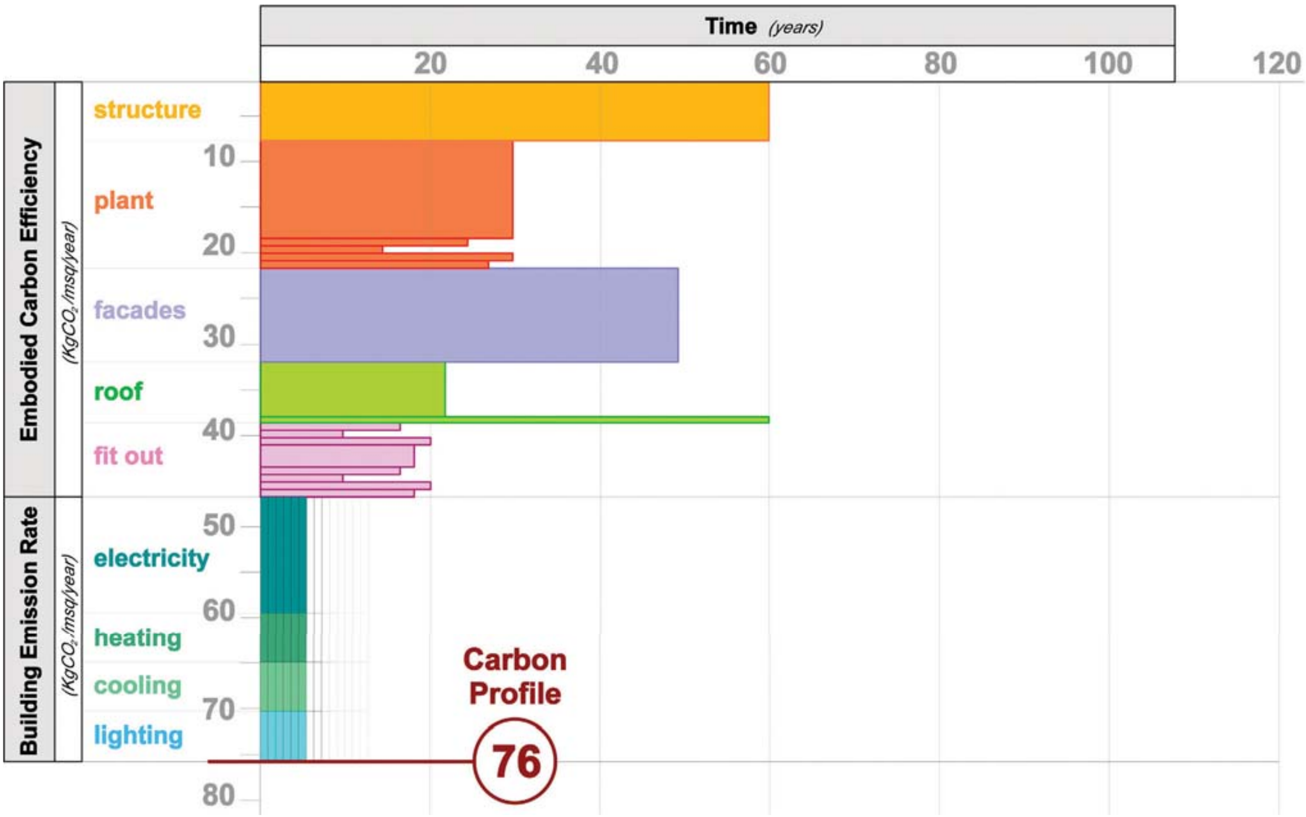
Where the Carbon Profile is being compiled for the first time the components will be assessed against their replacement value in the context of a newly formed component today of similar specification. The only adjustment will be the recorded design life differences. For example a concrete slab, which may have a residual lifespan of 50 years when compared to new replacement slab of 100 years, will have the same embodied carbon but just different lifespan assumptions.

It is acknowledged that this may provide a different weighting to existing stock emissions from buildings, which have already had a Carbon Profile carried out previously. But trying to estimate retrospective carbon emissions going back over a hundred years or more is a very unreliable task due to the lack of data. It is also recognised that this modern day approximation of existing resource values would over time be overshadowed by subsequent assessments and components reaching the end of their design life. Therefore any errors would be minimized over time.

Where a system has completely failed, and can be said to have reached the end of its design life, then its only value is in any carbon resource that can be salvaged from recycling. These figures are only included if it has occurred, and not if it is simply left as a possibility for others in the future to carry out.

Figure 12 presents a graphical overview of emissions generated, where the area of each bar represents the total emissions generated and its length represents the time in which the items formed will be used before being replaced. Using this method of representing emissions, it becomes clear which parts of the fabric have longer lasting impacts and their relative importance can be assessed by the heights of each bar. For instance in comparing the structure and the facades it should become clear that although similar amounts of emissions are required to create both, the impact of the facades is greater by virtue of their shorter lifespan as an element of fabric.

Figure 12 Detailed overview of Carbon Profile



Formulae

Figure 13 Formulae and Key

$$\underbrace{A^{-1}\left[\sum_{n=1}^{N} x_n\right]}_{\text{BER}} + \underbrace{A^{-1}\left[\overbrace{\left[\sum_{j=1}^{J} \frac{y_j}{l_j}\right]}^{\text{Independent Components}} + \overbrace{\left[\sum_{b=1}^{B} \left(\frac{\sum_{t=1}^{T} y_t}{\min l_t}\right)_b\right]}^{\text{Linked Component Systems}}\right]}_{\text{ECE}}$$

A	Net Internal Area of building
X	Element giving rise to operational emissions
y	Component giving rise to embodied carbon emissions
l	Lifespan of component
N	Set of elements giving rise to all operational emissions
J	Set of all independent components
B	Set of all linked component systems
T	Set of all components comprising an individual linked system

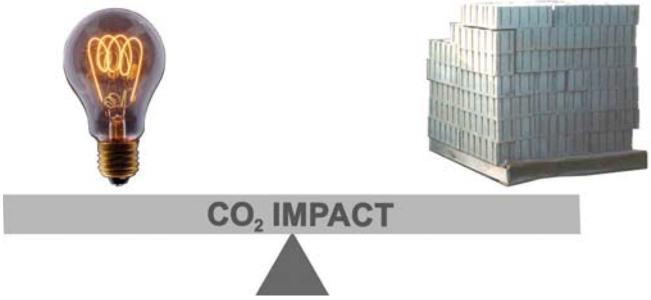
Case study: Ropemaker Place

Key findings

STURGIS CARBON PROFILING LLP (part of Sturgis Associates Architects) have carried out a detailed post completion Carbon Profile study of the building based on information provided by the contractor (Mace) and the sustainability consultants (dcarbon8).

The general finding of the study makes surprising reading to those not conversant with whole life costing approaches.

The Carbon Profile for Ropemaker Place shows that over half of the building's CO_2e impacts are attributable to embodied carbon.



In fact this figure is much higher than the initial expectations of the study team as well. This is in part down to the success of the numerous operational carbon emission reduction measures on the project, but it also does suggest that to build on these achievements equal regard now needs to be given to the embodied as well as the operational emissions from modern high performance buildings.

Overview

Ropemaker Place is a 20 storey, 80,000 m^2 office development by British Land Plc located on Ropemaker Street on the boundary of the City of London and the London Borough of Islington. It was completed in May 2009 and is at present finished to 'shell and core' standard.

Developer – British Land PLC
Consultant Design Team: Architects – Arup Associates
Structural Engineer – Arup Associates
M&E Engineer – Arup Associates
Contractor – Mace

Over the coming years the building will be sub-let to different institutional occupiers. The first of these will be the Bank of Tokyo-Mitsubishi UFJ, Ltd and Mitsubishi UFJ Securities International plc who will be taking 17,000 square metres of space in January 2010, and will fit out the floors for their use to BCO Category C specification from 'shell and core'.

The building incorporates many sustainable features:

- Tilting facades, to reduce solar gains
- Green roof – Rainwater harvesting
- A woodchip boiler
- Waste recycling facilities for the use of occupiers
- CO_2 emissions 15% lower than 2006 Building Regulations
- All timber sourced from sustainable managed sources
- Solar water heating
- Photovoltaic panels.

As a consequence, it has been awarded:

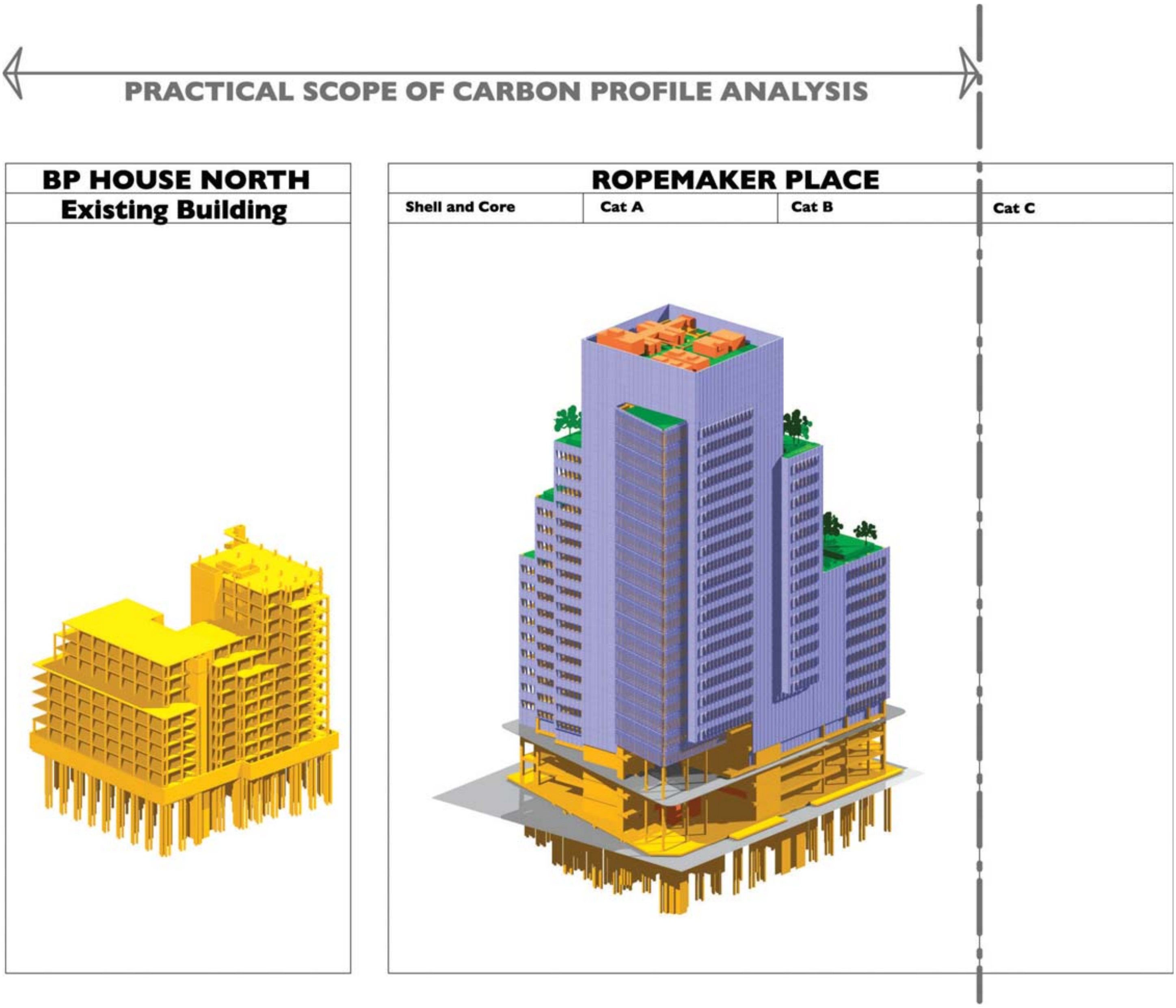
- BREEAM Excellent Rating
- 2008 Estates Gazette Green Building Award.

Scope

The Legal Scope for Ropemaker Place's Carbon Profile involved the examination of the relationship between the landlord and tenant related carbon emissions, and how these may adjust at different occupancy levels inside the building. The Practical Scope involved the requirement to define the value of the previous building on the site which in this instance was BP House North, shown in figure 14. This proved to be a complex task as the building was cleared prior to British Land purchasing the site. However, with the information from Building Control and the planning archive a clear picture of the property was developed.

The following diagram shows the scope of the Ropemaker Place Carbon Profile study

Figure 14 Scope covered in Ropemaker Place Carbon Profile



Case study: Ropemaker Place

Key Component Analysis

Over the following pages in figures 15-19 the key component systems are broken down and analysed to discover their interdependencies and the weakest links.

Figure 15 A summary of the main component's systems inside Ropemaker Place

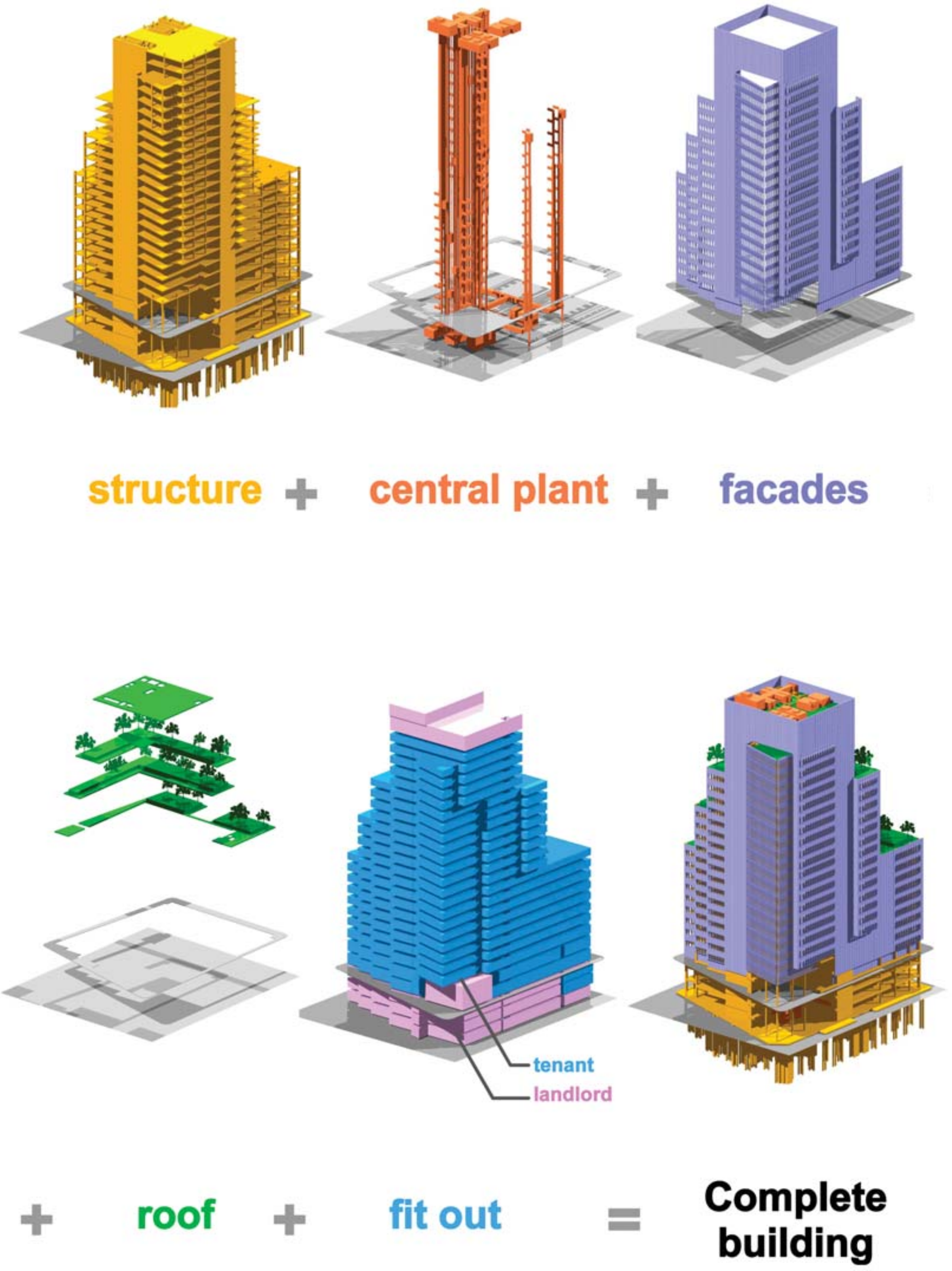
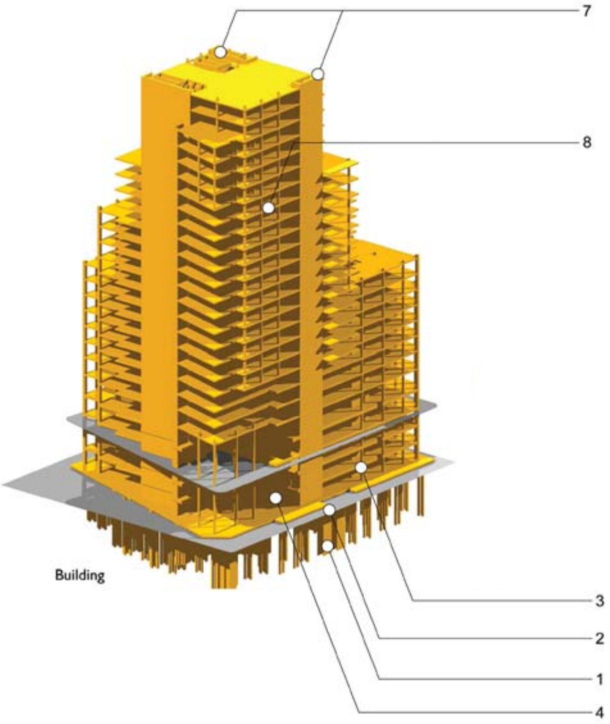
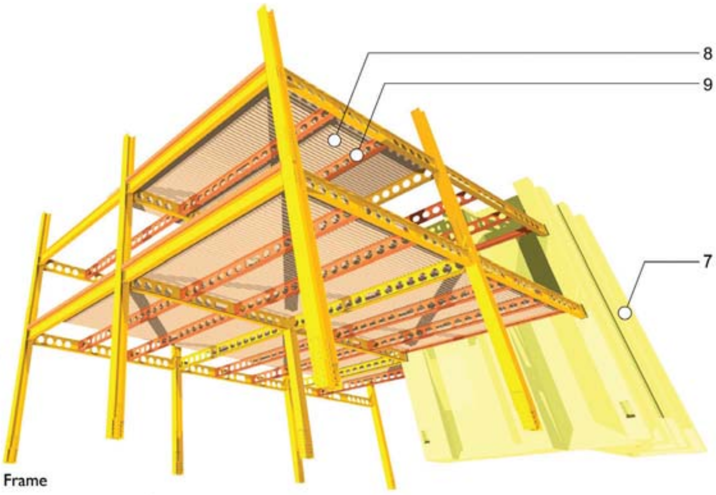


Figure 16 The structural components systems inside Ropemaker Place



weakest link

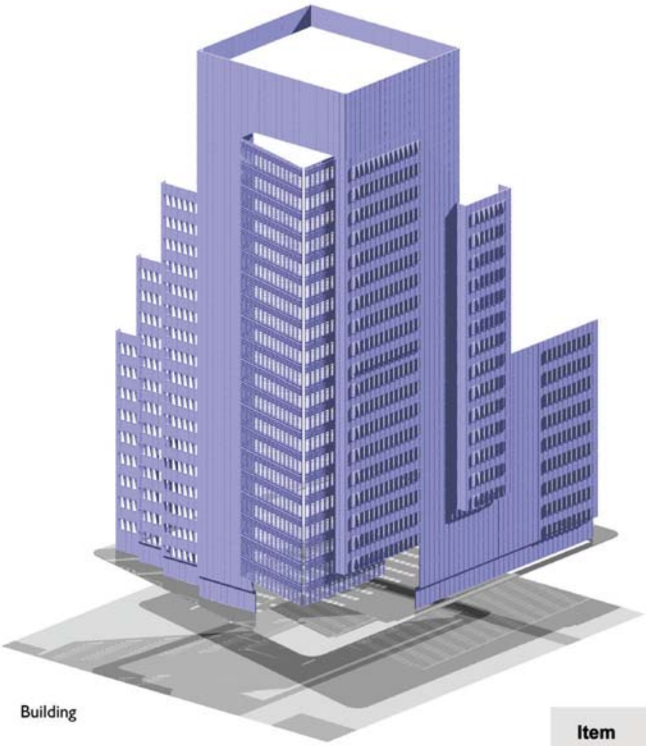
Item	Components	Median Life Expectancy Typical	Minimum	Maximum
1	Piles and Pile Caps	100	60	120
2	Other (aggregates)			
3	Basement slabs & ground bearing slab	60	30	90
4	Basement frame (Column & Beams)	75	45	100
5	Cores (sub structure)	75	50	100
6	Basement walls	60	30	90
7	Cores, lift & escalator shafts, staircases	75	50	100
8	**Floor Slabs**	**60**	**40**	**100**
9	Main Building Frame (Columns & Beams)	75	50	100
10	Internal Structural Walls	75	50	100



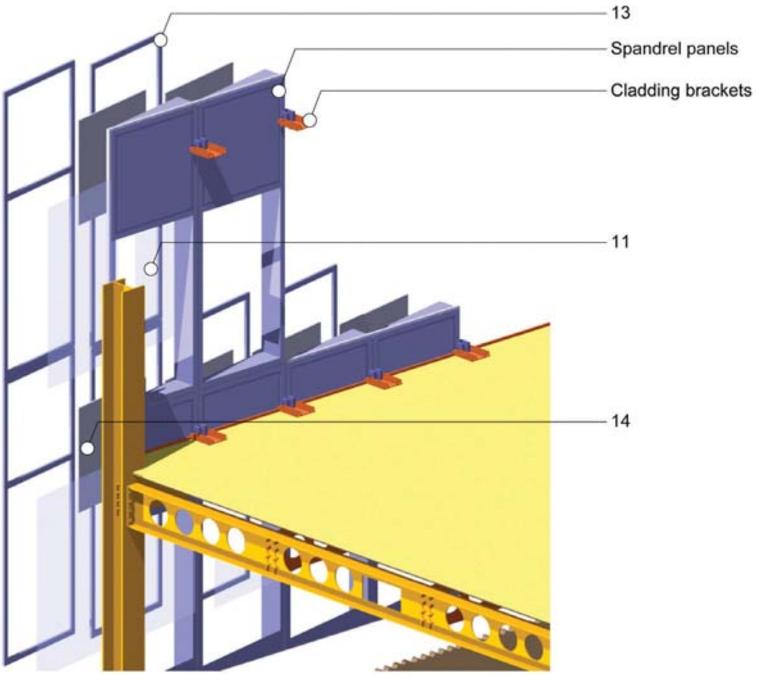
Source: BCIS Life Expectancy of Building Components

Case study: Ropemaker Place

Figure 17 The facade components systems inside Ropemaker Place

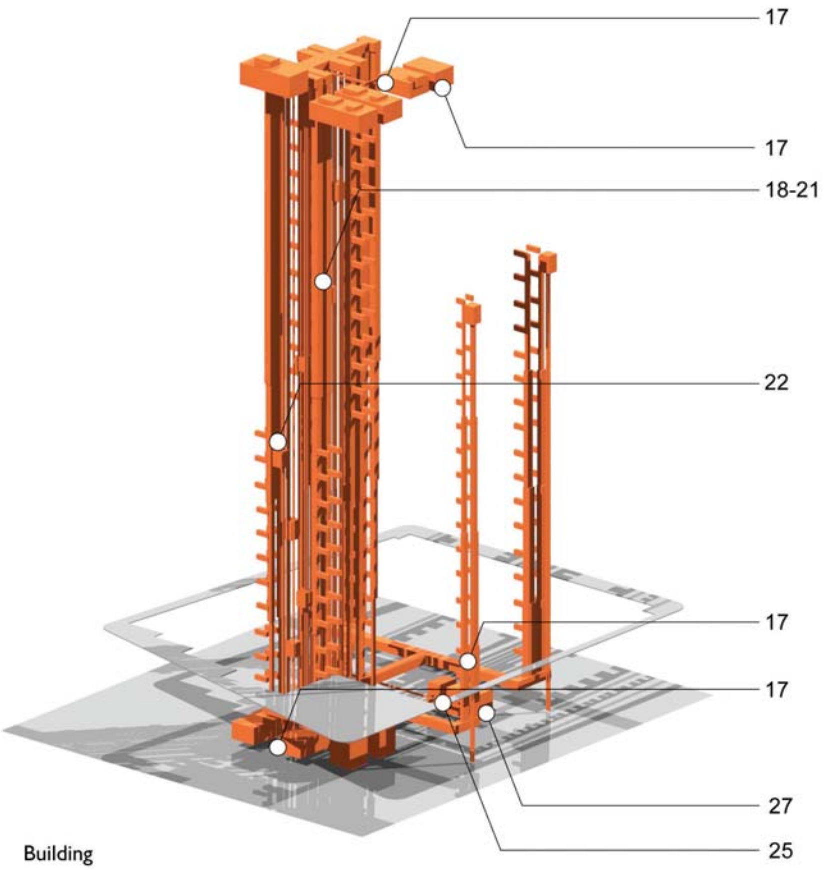


Item	Components	Median Life Expectancy		
		Typical	Minimum	Maximum
11	Double Glazed Units	30	15	35
12	Louvring	40	30	57
13	Glazed Cladding Units -frames	40	30	57
14	Glazed Cladding Units -insulation	40	30	57
15	External doors	40	30	57



Source: *BCIS Life Expectancy of Building Components*

Figure 18 The central plant components systems inside Ropemaker Place



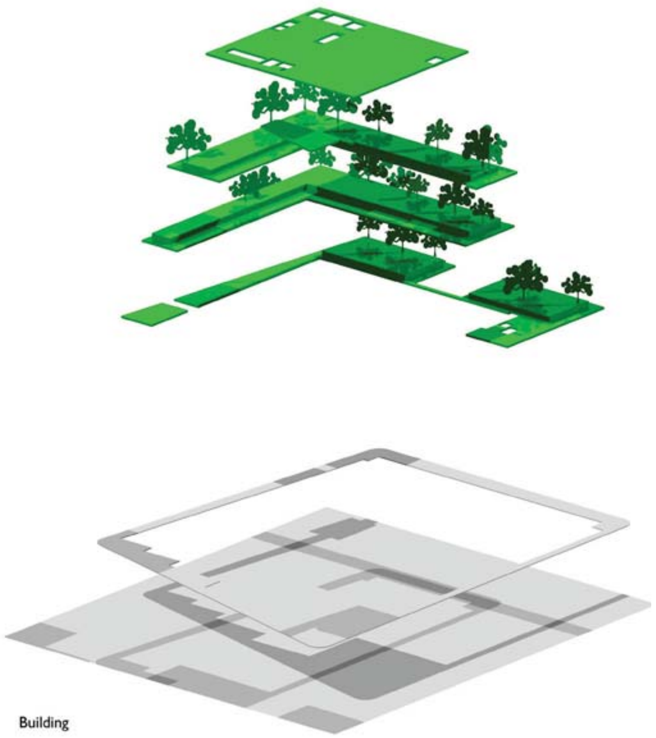
weakest link

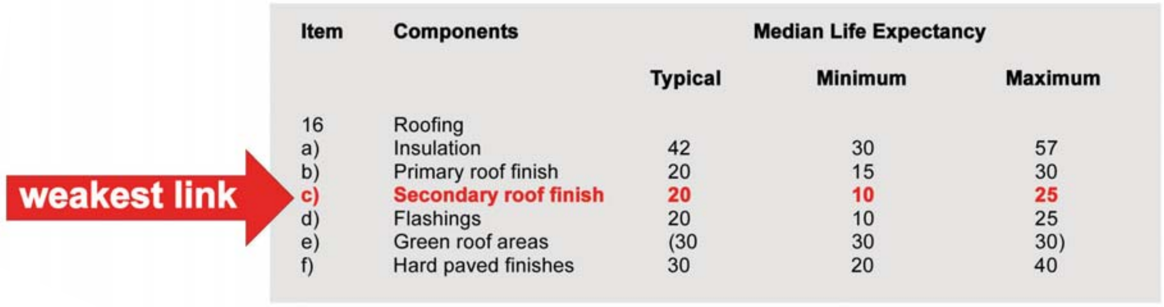
Item	Components	Median Life Expectancy		
		Typical	**Minimum**	**Maximum**
17	Central Plant	20	10	27
18	Water Supply and distribution	40	25	50
19	Space Heating & Cooling Systems	25	15	30
20	Air Handeling and ventilation	30	20	35
21	Electricity Supply and Distribution	30	20	32
22	Transport (lifts, escalators)	25	20	40
23	Communications & IT	25	20	30
24	Protection Systems	25	20	30
25	Drainage	50	32	60
26	Gas and Fuel Installations	25	20	30
27	Renewables	20	10	27

Source: BCIS Life Expectancy of Building Components

Case study: Ropemaker Place

Figure 19 The roofing components systems inside Ropemaker Place



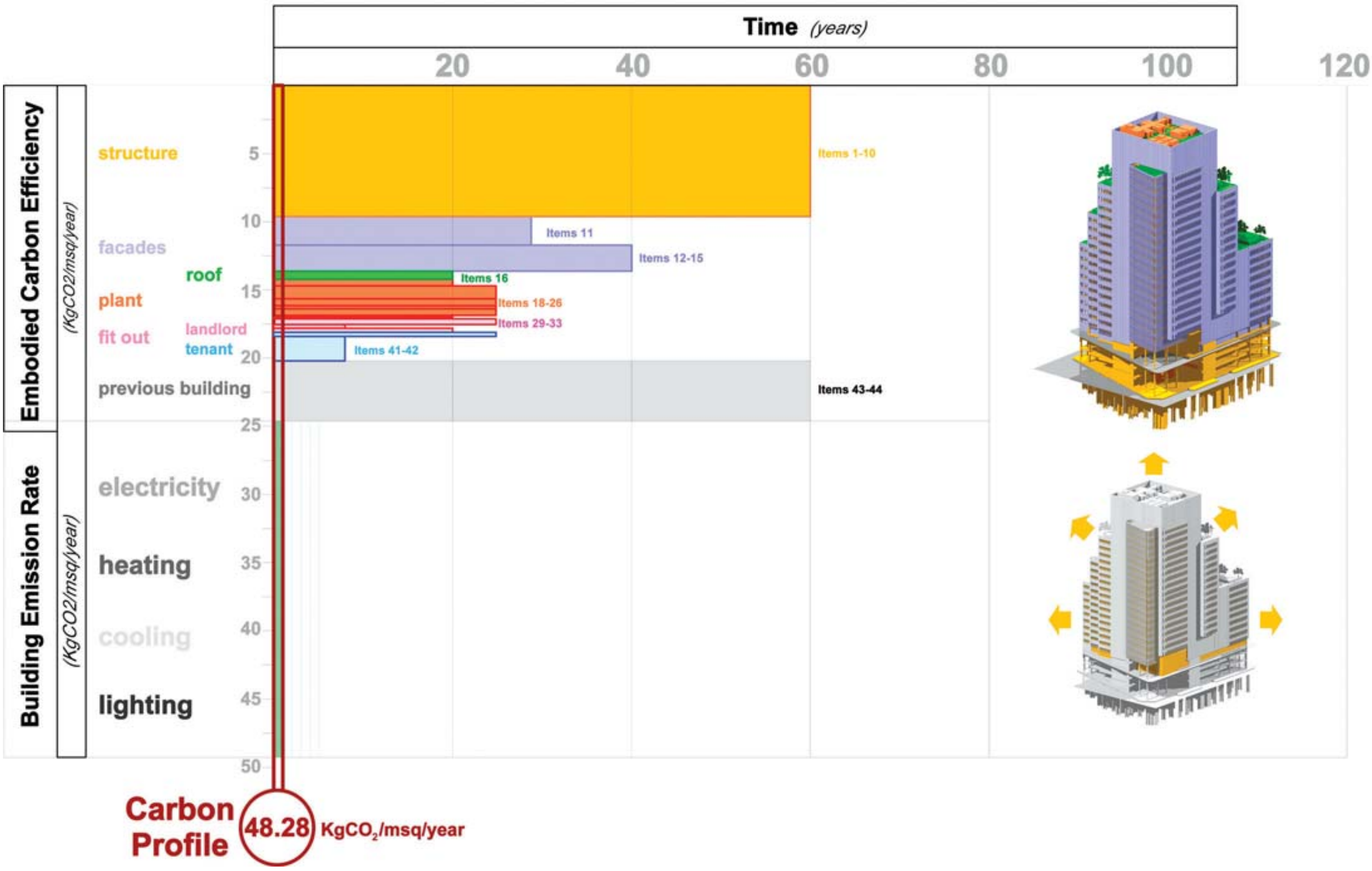


Item	Components	Median Life Expectancy		
		Typical	Minimum	Maximum
16	Roofing			
a)	Insulation	42	30	57
b)	Primary roof finish	20	15	30
c)	Secondary roof finish	20	10	25
d)	Flashings	20	10	25
e)	Green roof areas	(30	30	30)
f)	Hard paved finishes	30	20	40

Source: BCIS Life Expectancy of Building Components

Figure 20 Ropemaker Place Carbon Profile

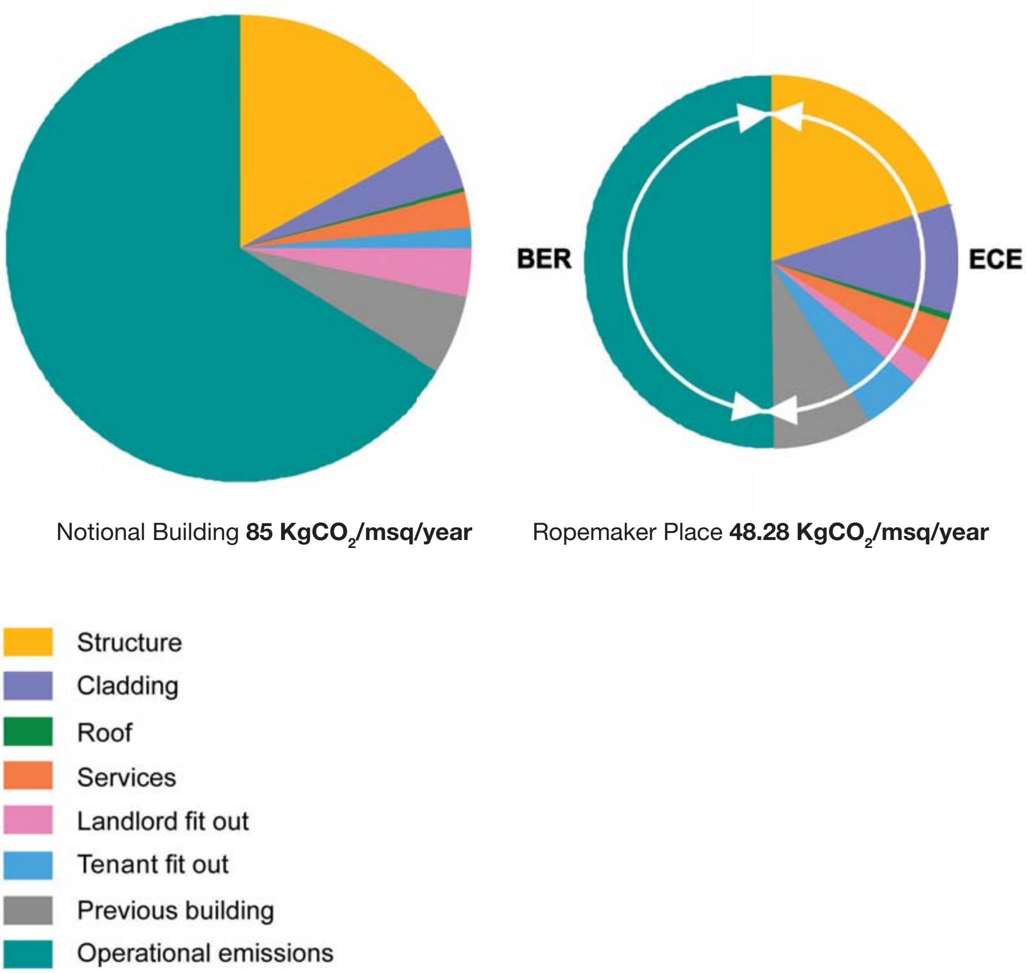
Here the aggregate picture is formed by factoring in the Building Emission Rate data, to provide the whole life efficiency rate, i.e. the building's Carbon Profile.



Case study: Ropemaker Place

A Summary of the Carbon Profile

The overall Carbon Profile of the building is 48.28 KgC0$_2$/msq/year, which is split into an ECE of 23.68 KgC0$_2$/msq/year and a BER of 24.6 KgC0$_2$/msq/year. The impact of the different emission sources is identified below, in the pie chart.



Notional Building **85 KgCO$_2$/msq/year**

Ropemaker Place **48.28 KgCO$_2$/msq/year**

At first glance what is strikingly apparent is the overall size of Ropemaker Place's Carbon Profile in comparison with a notional building (notional defined in terms in The Part L 2006 as using the 2002 standards as a baseline to measure reductions against). Here the building is shown to be performing overall 63% less than its notional equivalent. What is also apparent is that the majority of these improvements are focussed on the operational side of the Carbon Profile. So much so, that the embodied is now the more dominant part of the overall picture.

Brief Appraisal

Ropemaker Place shows a considerable range of impressive operational carbon emission reductions that are clear from its BER – placing it well ahead of the current statutory requirements for office buildings of this type. Its ECE is assisted by a good perimeter to floor area ratio, which minimizes the embodied carbon costs of the cladding in relation to the building as a whole.

The advice provided to incoming occupiers is to take care with their fit out to preserve Ropemaker Place’s good operational performance figures. Measures such as zoned lighting and cooling with Passive Infra Red (PIR) detectors will help achieve this. Likewise for the embodied carbon position, a detailed analysis of the fit out should be carried out pre-tender with particular attention to finishes such as carpet tiles, as these account for a high percentage of whole life emissions for interiors.

With the ECE and BER figures, and the combined Carbon Profile a number of questions can be answered, such as:

- How does the building rank in comparison to other buildings in its class?
- Is the ECE or the BER under- or over-performing?
- Are the marginal costs of emission reductions in the embodied the same as in the operational?
- Identify sources of substantial emission reductions so that lessons can be learnt for future projects
- Establish when most of the building’s emissions will be placed into the atmosphere, i.e. the date of the building’s time weighted average
- Identify simple measures that could be undertaken to reduce the building’s Carbon Profile by addressing the weakest links at this stage
- Develop targeted maintenance strategies to begin the synchronizing of component lifespans
- Have the materials selected proved to be the most efficient in embodied carbon performance.

Risks Errors

The main uncertainties that lie in the model are attributable to the following areas:

- Embodied carbon data
- Lifespan data
- Building measurement data
- Subjective interpretations.

The first two pose the most serious opportunity for creating bias in the results, and this is why this information should be taken from the common sources identified below. It is believed that the remainder should be minimized by the establishment of a best practice procedure, which itself should form a separate follow up study to this.

The sourcing of Embodied Carbon Data

We have used data provided by the University of Bath ICE (Inventory of Carbon and Energy), developed by Professors Geoff Hammond and Craig Jones[12] in 2006. This data set represents weighted industry averages, but it is clearly possible to source specific material values to achieve lower (or higher) embodied carbon contents, e.g. aluminium made with hydroelectric power has a very different embodied carbon value to aluminium that is produced using fossil fuels.

Two issues should be clarified at this point. Firstly it should be noted that many have also developed databases of embodied carbon information. As with cost information this data will vary in detail from source to source. Does this matter? Probably not, so long as the methodologies for collection are consistent and there is consistency in using one source for one model, and for any ordinal comparative work. Secondly, the accuracy of the data required should be dependent on the specific requirements at the given stage of the decision-making process. Again, as with cost analysis, it is our view that the information needs to be sufficiently accurate for the task in hand. Therefore, at the feasibility stage of a new project, what is required is generic carbon information to enable a general carbon strategy to be established. This should be followed up with more refined data as the project becomes more detailed and overall carbon targets are established. The logical conclusion of this is to require carbon use information with the tender, and monitoring of carbon use on site.

As a general conclusion, the aim should be to establish the Carbon Profile of a building using actual sourced data from suppliers. This is subject to the information being examined for accuracy and contractor bias. Where the sourcing of this data proves impractical, stock data should be used, accompanied with a justification for its applicability on the particular project.

A secondary source of errors with the Bath ICE data may be the conversion of its values to account for transport to site and assembly. To minimize these errors, Department of Environment, Food and Rural Affairs (2007) data is used to make the adjustments. The overall error impact of these figures is likely to be small, as site works, although important, typically don’t generate a large percentage of emissions. Studies by Smith (2007) place this at 5% or less. That said, further investigation into reconciling these two data sets will be necessary.

Estimating the Lifespan of Components

With new construction work, this data is based on the BCIS (2006) survey report taken from questions answered by 92 individual building surveyors located in the United Kingdom. The conditions for the survey are that all components are:

- Installed in accordance with the manufacturer’s instructions or other recognized methods
- In compliance with all relevant regulations governing installation and use
- Subject to moderate exposure
- Maintained either in accordance with the manufacturer’s guidelines or with the guidance of other suitably qualified persons.

Using data of this kind may give rise to regional bias, e.g. the fabric of a building located beside the sea may have a shorter life expectancy to the average figures in the BCIS data. At present the authors believe that this bias risk is small, partly due to the fact that it is likely to affect an entire local market and not just isolated buildings. Therefore local comparative evaluations will still hold even if city to city bias may still remain. In the context of using Carbon Profiling to aid occupiers to make locational choices, the local market comparisons are by far the more important. In time a follow up study may be needed to investigate the magnitude of this regional bias. If proved to be significant a regional scalar could be introduced to help minimize this.

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[12] *Hammond, G., Jones, c., 2006. Inventory of Carbon & Energy (ICE) Version 1.5a Beta*

Defining the weakest link

Any component system of a building (the structural frame, external cladding, services etc) is a combination of many different parts. Some of these parts are capable of independent replacement, e.g. the glass in a window, but others are linked together e.g. a prefabricated wall panel. The lifespan of these linked systems will therefore be at the mercy of the weakest link. A case in point was Britannia House (an office tower block) in the City of London. This had stainless steel cladding connected to the structure by galvanized fixings. These connections condemned the cladding to an unnecessarily early demolition, thereby wasting a huge carbon asset. So, identifying weak points early in the design stage is critical to prolonging the life of a building.

However it is should also be recognised that defining what is and what is not a weak point is at present a subjective process and may lead to errors in carrying out a Carbon Profile. One method for standardizing this would be to pool all Carbon Profile assessments so that guidance may be developed on identifying the weakest link for common component systems.

It is the belief of the authors that building designers should design building systems with as far as possible synchronized lifespans, or should ensure that they are capable of easy maintenance or period replacement to mitigate carbon wastage.

Though more work may be done to minimize the risks in the model, the key sources of errors are being addressed by the use of common data sets. Where other bias exists, this will mostly be small or be regionally based and so will not affect local comparisons.

> **“The lifespan of these linked systems will therefore be at the mercy of the weakest link**

Implications and issues

ALONGSIDE THE DESCRIPTION of Carbon Profiling this paper intends to introduce a couple of other related topics, which in themselves are not dealt with in great detail but which combined provide a broader context to the debate around this subject. These comments are not meant to be exhaustive, but more basic investigations that may form the starting point for further work, perhaps by others, or to just provide the reader with some alternative viewpoints.

Issue 1: Implementation Challenge – CO_2 Reduction Policy in the UK: state or market driven mechanisms?

With ratification of the Climate Change Act on 26 November 2008 the UK has committed itself to some of the broadest reaching reductions in CO_2 emissions of any developed nation. A legally binding target of 80% reduction in CO_2 emissions by 2050 has been set, with an interim target of 34% by 2020[13].This has placed the UK right at the heart of the climate change debate and the challenge of how to find solutions to achieve this.

The origins of the Act come from the signing of the Kyoto Protocol in 1997 which formalized a framework agreement signed in 1992 that set targets for developed nations to cut their greenhouse gas emissions. The Kyoto Protocol became a legally binding treaty on 16 February 2005. In addition, the recent agreements from the United Nations Climate Change Conference (COP 15) in Copenhagen, 7–18 December 2009, have established CO_2 reductions as a global effort in which the construction industry must play its part. This is crucial as the construction industry accounts for 40% of total carbon emissions created in the developed world[14]. Emerging nations such as Brazil, China and India know that their future projections will be similar if not worse.

With these headline reduction figures and the size of this challenge the UK government now faces the task of delivering these and convincing businesses and individuals to buy into the agreed timeline.

A major part of this strategy will involve producing clear guidance as to what exactly will be required, and which targets will apply to whom. Early identification of any support that there is on offer to achieve this will also be essential.

The UK Low Carbon Transition Plan of the Department of Energy and Climate Change, which was laid before parliament on 15 July 2009, makes a start on this process by assigning to different sectors their share of the overall carbon emission reductions (see figure 21). This begins to allow industry and individuals to see how the burden of achieving these reductions will be shared, which should in turn act as a signal for resources to begin to be channeled to deal with achieving these goals. Alongside this, however, are the many existing strategies and laws that have already been introduced over the past 10 years to help lower UK carbon emissions. The challenge now facing legislators is to integrate this existing legislation with the new sector-wide targets, and at the same time close any remaining loopholes that current legislation is not covering.

A key requirement for the construction industry therefore will be to agree on a simple, common and understandable carbon measurement system such as Carbon Profiling. Without this it will not be possible to determine the impact of the reduction measures taken, or indeed which measures are the most efficient to take.

Having established the UK government's targets to change business and industry behaviour it is also worth examining now how consumer demand could be used as a means of reducing carbon emissions, to provide an alternative to excessive carbon taxation, and limiting mechanisms to achieve the same goal.

The first part of this process is the dissemination of information to consumers, in which green labeling and Carbon Profiling could become an essential part in the context of the built environment. A question still remains however. Will enlightened self-interest be enough to encourage consumers to allocate their resources in the most environmentally efficient means? Or will the age-old problems of the non-excludability of public goods such as clean air and the enjoyment of biodiversity mean that we will all wait for someone else to make the move for us to take the benefit?

In this context should Personal Carbon Allowances be re-examined?

Such a system does have many drawbacks in terms of voter buy-ins, the cost of delivery, and transparency issues for whoever operates it. At the same time these complexities should be considered against the benefits of removing the many separate policies that will need to be introduced to achieve the targets, and the inherent welfare inefficiencies that they will introduce.

Perhaps given the importance of this issue and the amount of money being estimated to deal with this, (1–2% GDP over the next 50 years, as recommended by the Stern Review) this may be a good moment to step back and consider which other mechanisms could exist to help achieve these goals.

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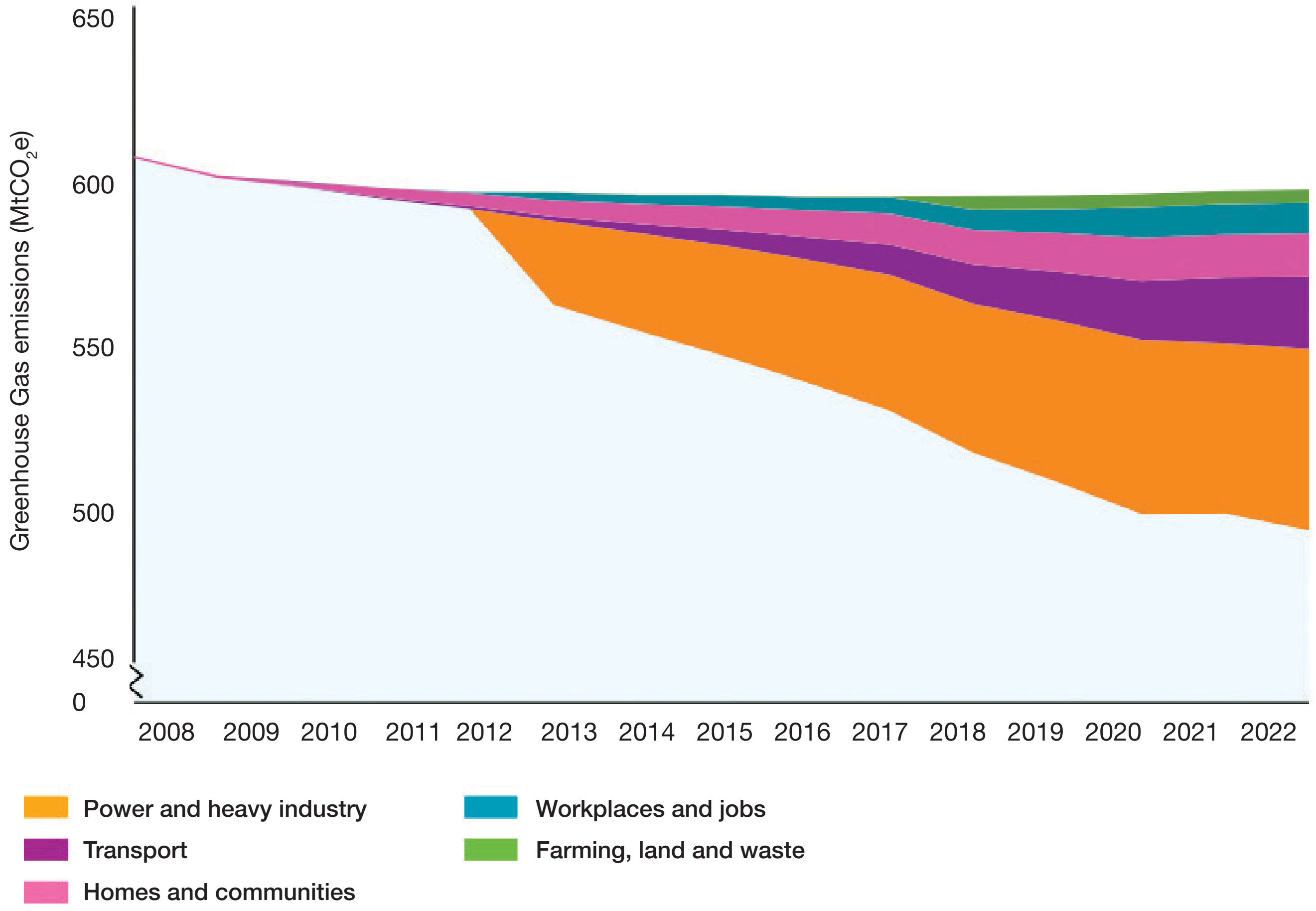
[13] *HM Government, 2009. The UK low carbon transition plan. London: The Stationery Office.*

[14] *United Nations Sustainable Buildings and Climate Initiative, 2009, Common Carbon Metric for Measuring Energy Use and Reporting Greenhouse Gas Emissions from Building Operations, UN,*

Figure 21 How the challenge will be shared



Source: Department of Energy and Climate Change

Note: The impact of policies prior to the 2007 Energy White Paper is included in the baseline; without these policies, UK emissions would be higher.

Issue 2: Building Value Depreciation and Embodied Carbon

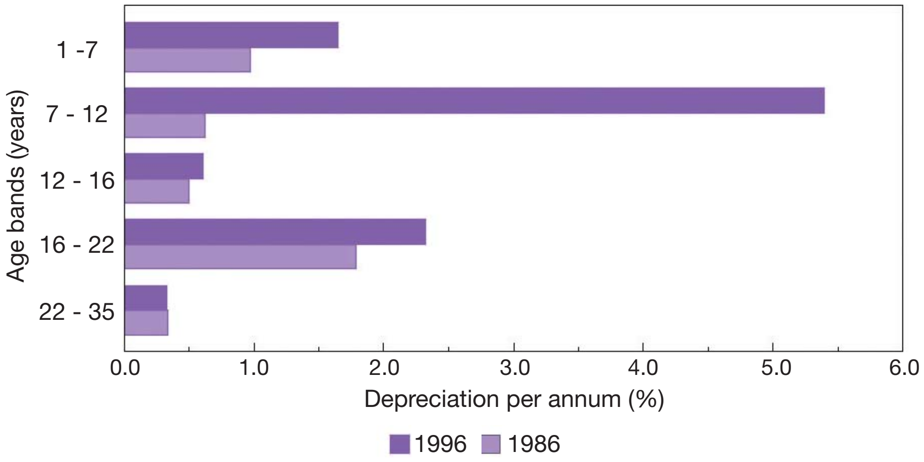
Depreciation of value and deterioration of fabric over time are interlinked issues that every building has to deal with. Minimizing the deterioration of the fabric also has positive effects on a building’s embodied carbon performance, by reducing the frequency of required carbon expenditures on maintenance. Strategies for aligning expenditure on components of a building to protect the building’s value (i.e. future-proofing) and thus improving the embodied carbon efficiency are important to understand and develop.

Carbon Profiling has the benefit of describing the future carbon performance of a building through lifespan analysis. By examining this it is possible to protect/enhance the value of an asset in the following ways:

- Minimizing the deterioration of the fabric to enhance present values (implicit in the reduction of capitalization rates)
- Synchronize the end of life of key components to reduce mid-life replacement and wastage, thereby introducing scale efficiencies into the refurbishment process
- Pinpointing the optimal carbon future points to refurbish or rebuild, thereby reducing risk
- Aligning refurbishment and lease cycles to enhance/rationalise future cashflow.

Work by Andrew Baum and Anita McElhinney[15],‘The causes and effects of depreciation in commercial space in the UK’ provide additional insights into this. Baum and McElhinney report that, as buildings age, their inflation-adjusted values tend to decrease in a non-linear relationship (see figure 22). This is due to a variety of effects, such as obsolescence and fabric deterioration impacting at different times. Most of the results indicate capital values tend to fall by between 0.5% and 6.5% per annum, with the majority of these losses happening in the first 16 years after construction. This poses the question of what the causes of this depreciation are.

Figure 22 Depreciation in smoothed ERV over time



Andrew Baum, University of Reading/RICS The causes and effects of depreciation 1997.

Interestingly, the deterioration of fabric and internal specification were considered to be the main determinants of depreciation (see figure 23), and the external appearance the least. This proves to be particularly useful as it marks a change in depreciatory drivers from the incurable to the curable (a previous report by Andrew Baum in 1986 indicates configuration to be the greatest cause of depreciation). This current trend identifies the durability of buildings as being increasingly important in the future-proofing of asset values.

Figure 23 Depreciation in smoothed ERV by factor

	Parameter	T-ratio
Constant	4.15	
Exterior	0.49	0.70
Interior	2.90	4.03
Configuration	0.66	1.13
Deterioration	2.19	2.96
R squared	0.68	

Andrew Baum, University of Reading/RICS The causes and effects of depreciation 1997.

Issues that need to be considered are:

- Durability of materials
- Components well designed for maintenance
- Quality of internal specification.

These observations also have a strong correlation with some of the key principles of low carbon design, which focuses on buildings lasting longer and pushing into the future the effects of physical deterioration of the fabric. This indirectly links designing for low carbon use with retention of building value, and maximization of income.

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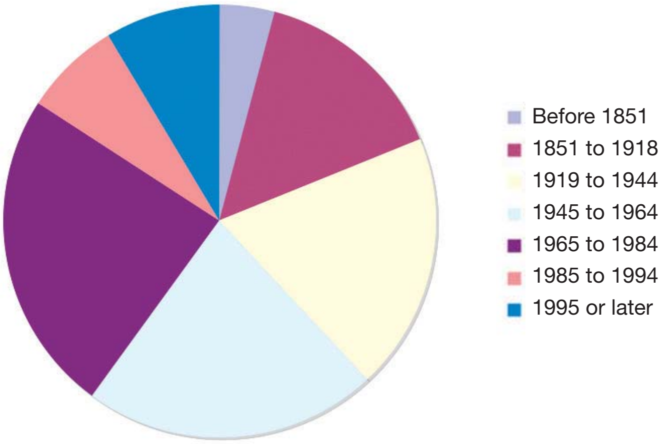
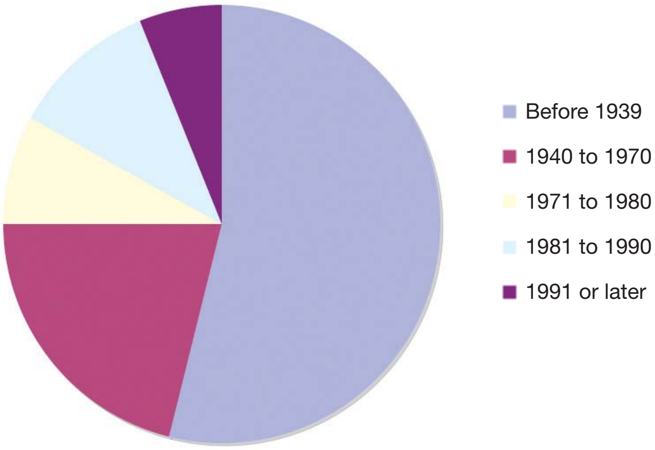
[15] *Baum, A. and McElhinney, A.,1997. The causes and effects of depreciation in office buildings: a ten year update. RICS, London*

Figure 24 Age of UK Residential Housing Stock



Age **distribution of the stock is estimated from the 2007/08 Survey of English Housing, using results for the period April 2007 to March 2008.**

Figure 25 Age of UK Commercial Stock



Age proportion of hereditaments, England and Wales 2007. Department for Communities and Local Government

Issue 3: The Role of Refurbishment

There are around 29 million buildings held in various forms of tenure in the UK[16]. Of these the vast majority are residential (around 26.5 million) and the remaining 2.5 million are a mix of offices, industrial and retail units. 60% of these buildings were built before 1964. Their distribution of ages are shown in figures 24 and 25.

Many of these buildings have a large number of years of useful life left but, with different construction techniques from different periods, it makes it difficult to analyse them, especially when their operational emissions will also vary greatly.

The benefits of Carbon Profiling are that it makes it possible to simultaneously analyse an existing building and its proposed replacement in terms of its carbon efficiency. It enables an informed choice to be made between a refurbishment with less than perfect operational emissions but with substantial retention of embodied carbon, against a new build with excellent operational use but requiring large initial embodied carbon expenditure. Armed with this information, targeted retrofitting techniques may be developed to optimise the carbon performance of existing buildings, and also to discover which buildings are beyond beneficial improvement, i.e. at the end of their carbon useful life, and should therefore be considered for replacement and component recycling.

This targeted approach has many advantages as it switches the focus from new buildings, which are only around 1–3% of the nation's stock in any one year, through to the existing buildings where significant improvements can be made, often much more cheaply. These issues could be examined as part of a local authority's unitary development plan (UDP) policies and the rate of Section 106 contributions that developers are required to make.

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[16] *CLG, 2004, 2009b*

Implications and issues

Issue 4: Carbon Trading

Carbon Profiling may be used to demonstrate a level of achievement on projects that exceed statutory requirements for emission reductions, thus making it possible to achieve Emission Credits (ECs) or Voluntary Emission Reductions (VERs), in certain circumstances. In countries that are classed in the Kyoto Protocol as Annex B countries, e.g. India and China, Carbon Profiling may also be used to justify Certified Emission Reductions (CERs), which have significantly greater value and may be traded much more easily through the EU Emission Trading Scheme (EU ETS). The issuing of Carbon Credits through Carbon Profiling has two objectives. One is to raise the baseline level of building efficiency and the other to reward those that go further in reducing their carbon emission impacts.

Allowing developers the possibility of claiming carbon credits also has many beneficial land market impacts, potentially mitigating the legislative costs associated with compliance to zero carbon. This will have considerable benefits to occupiers in much of the UK where currently excessive land supply restrictions results in the majority of cost increases being passed on to occupiers.

Emission trading originally came about from the ‘cap and trade’ system introduced into various markets to try to incentivize the reduction of carbon emissions by large polluters, such as power stations and energy intensive factories. The largest scheme to date is the EU ETS which was set up in January 2005 to allow large polluters the option of either reducing their emissions down to committed levels (the ‘cap’) or buying permits (the ‘trade’) as a way to offset this. At present the EU ETS is in its second trading period. This is due to close in 2012 at which time all credits will have to have been allocated. The third period is due to start in January 2013 when the trading proceeds and allocations to each member state are due to become centralised.

Alongside the EU ETS, which trades CERs, many secondary markets have also formed to trade products such as VERs or ECs. This occurs through Registries such as the Bank of New York Mellon. These secondary products have the advantage of being able to be sourced from countries other than the Annex B countries identified in the Kyoto Protocol.

The basic characteristics of any type of Carbon Credit is that the emission savings it represents are demonstrably “additional” i.e. that without the existence of the credit as an incentive the measure would not have taken place.

Many of these emission reductions may be achieved through the alternative specification of building components that allow for low carbon technologies or materials to be used that reduce the whole life carbon footprint of a scheme. These measures need not be complex and may be as simple as re-using existing steelwork on a site as part of the new construction. Carbon Profiling a building or design offers the possibility of discovering where demonstrable “additional” emission reductions on any project may be achieved. Then, depending on the location of the project, the appropriate credit may be awarded for trade in these markets.

Carbon Profiling provides a simple way to engage with these emerging markets and offers the potential to developers to benefit by engaging in low carbon design, where legislation is not the main driver.

Issue 5: Development control and carbon reduction

Carbon Profiling provides a method of explaining how carbon efficient a proposal is. The method is scalable, thus allowing the possibility of analysing a range of activities from individual building components through to master planning proposals at the urban scale. This ability of the model to be as focused or as broad-reaching as the job requires makes it a particularly powerful design tool as it can track through all of the different stages of a project’s development.

The mechanism for allocating this through the planning system could be similar to national housing stock targets, which are converted into borough and district policies. This may give rise to borough-scale carbon allocations, which could then feed down through local development control policies to individual site proposals. This could potentially become a complex process but it would have the benefit of linking the environmental impact of carbon emissions through to land, which is also a fixed resource. Such a location-focused approach may also help deal with some of the externalities of high land use densities which can inhibit as well as drive a city’s growth. With this kind of model developers could purchase additional carbon credits on top of their site allowances so as to make possible large developments, capturing the benefit of high property prices in specific locations.

The above concept does have some economic resonance as the price of property is a function of many attributes, capturing the benefits of the city as a whole and not just its site-specific qualities. Where market failures exist as a result of negative externalities such as CO_2 emissions, these should be identified and internalised into the pricing process in order to reduce society’s welfare loss.

In such instances, Carbon Profiling may be used to assess the impact of proposed developments and to reward those who use their carbon budgets in the most effective way. It also allows for the possibility of sites trading surplus budgets, which may exist as a result of other development restrictions.

Issue 6: The true zero carbon challenge

Currently, when we talk about ‘zero carbon’ we are referring to zero operational emissions. This, as explained throughout this paper, is a simplification of the true facts. However this should not necessarily involve the complete dismissal of the ‘zero carbon’ concept. In fact, by considering the combined net effect, it could prove to be a particularly interesting challenge to try to achieve a combined operational and embodied whole life carbon emission figure of zero.

This idea significantly raises the stakes of what is regarded as ‘excellent’ performance and poses many interesting challenges as to how to achieve this. For instance, should site-based sequestration be considered as a method to help reduce embodied carbon emissions generated through materials and if so, how could this be completed and managed?

Alternatively could net exports of electricity giving rise to carbon credits be used to offset against embodied carbon emissions generated through the creation of materials?

It is not possible to expand upon these issues in this paper, but it may prove interesting for others to develop more fully.

Issue 7: CRCs – A step too far or not far enough?

The carbon reduction commitment came into force this April, requiring business that use over 6,000MWh of half hourly-metered electricity during the period January 2008 to December 2008 to engage in a trading scheme with each other. These businesses will have to measure all their emissions arising from their direct activities. i.e. electricity and other fuel use. For each tonne of carbon dioxide emitted businesses will then be required to purchase a credit, which will initially be sold at £12/tonne. The proceeds from these sales will then be shared out among all members according to their relative carbon performance at the close of each trading period. At the moment there is a one year period of grace in which businesses have the opportunity to adapt and develop their reporting procedures. In April 2011 the first sale of allowances will take place, and October 2011 is when the first recycling payments will occur where participants will receive back their original allowances plus or minus any bonus/penalty payments dependent on their performance in their energy performance league tables.

This scheme will affect UK businesses in many ways, but we have identified two unintended consequences relating to the property industry, that in our view have the potential to affect the market over time:

One will be the reinforcement of the misplaced negative stereotype that refurbishment/redevelopment is a second best option to new build. This will come about as large business occupiers (facing the challenges of the CRC) will actively seek operationally efficient buildings. This will advantage new build as it is typically less costly to introduce operational emissions savings (the emissions covered by CRCs), into these buildings, creating a bias against refurbishment. This however will ignore the embodied carbon benefits of refurbishment that when analysed by Carbon Profiling may have outweighed the operational emission advantage in the new build comparable. This substitution effect will needlessly reduce the value of otherwise comparable assets depreciating the value of refurbished property. An associated effect will be that as a result of this accelerated regulatory depreciation of assets, more buildings will be demolished before the end of their usable life, leading to increased construction activity and the potential of greater emissions as a consequence.

A secondary effect will be felt in the lease details of tenanted buildings. Occupiers who pay for their own electricity and utility bills will be liable to include these, as part of their CRC carbon calculations. However if these items are provided by the landlord, the landlord will then become eligible. This will give rise to pressure from tenants for landlords to assume this responsibility, so as to minimize their own CRC liabilities and show demonstratable improvements over time. Where this cost can be passed on, some developers may be able to take strategic advantage of the recycling scheme to make profits. This may be possible as the carbon reduction abatement costs facing occupiers will typically be higher than those facing the developer and their own set of activities. Carbon Profiling would allow developers who have to take account of their on-site development activities as part of their CRC to take advantage of this, by targeting the methods which create the maximum carbon savings at the least cost.

> **“Carbon Profiling a building or design offers the possibility of discovering where demonstrable “additional” emission reductions on any project may be achieved**

Conclusions

Whether we like it or not, dealing with the carbon emissions of buildings is a complex issue that is here to stay. In this research, we have set out to examine how this can be achieved and what tools are available to enable this. Our findings identify that current approaches leave many questions unanswered and in themselves may be giving rise to a whole host of additional problems:

- Not including embodied carbon is a serious shortcoming of current legislation; in some circumstances it may effectively give rise to additional emissions being generated than if this legislation was not in place
- Achieving embodied carbon emission reductions is in most circumstances cheaper than achieving operational carbon emissions reductions. In many situations carbon efficient choices will be no more expensive than conventional construction
- Allocating construction spending should be treated no differently to any other resource allocation problem. Ensuring carbon savings are generated in the most efficient way should be the objective of legislators and developers alike
- Understanding the effects of time, i.e. the lifespans of materials and when emissions are generated is essential in making correct choices
- Current methods of assessing emissions have serious shortcomings. The use of inaccurate future assumptions, which have no bearing on decisions today, undermines much current analysis. Such techniques introduce unnecessary uncertainty, and limit their usefulness as design tools
- The current cost estimates of up to £500/msq[18] to achieve zero carbon may have other far-reaching macroeconomic effects with regard to the affordability of homes, and the competitiveness of businesses in the UK. It also touches on many social issues such as people's rights to own and the gap between rich and poor.

Our research, having identified these concerns, contends that there is the need for a simple comprehensive metric that is easy to understand and directly addresses these issues. In this paper we identify Carbon Profiling as the means to achieve this goal. Carbon Profiling has many benefits as it addresses both operational and embodied emissions and provides a whole life efficiency figure that is simple for occupiers and owners to understand and make comparisons. We also identify that Carbon Profiling will help provide some key insights into issues that currently evade analysis, such as:

- What constitutes a good carbon asset?
- Which is the better use of resources; refurbish or rebuild?
- What are the genuine net benefits from renewable technologies?
- As a designer, which materials should I chose to minimize the global warming impacts of my design?
- How can I compare different procurement methods from the view of low carbon design, and develop green tendering principles?
- What are the financial option values associated with low carbon design?
- How do I develop an active carbon management strategy to minimize costs and maximize carbon reduction benefits?
- How can I take advantages of the CRC as a developer?

It is our contention that, given the scale of the challenge the construction sector faces in dealing with climate change, maintaining an incomplete legislative measurement technique is a nonsensical position, especially given that non-reported emissions can be as great as 62% for some building types[19]. Carbon Profiling provides a simple effective solution to this problem.

Our failure to address these issues and to adopt a more rigorous measurement technique, such as Carbon Profiling, undermines our collective credibility as a responsible industry; the time to act is now.

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[18] *Miller V. 2007 High Price of Zero Carbon, Building Magazine March 2007 London: Building*

[19] *Lane, T., 2007 Our Dark Materials. Building Magazine, 2007, Issue 45, London: Building*

Appendix 1

General recommendations for all buildings

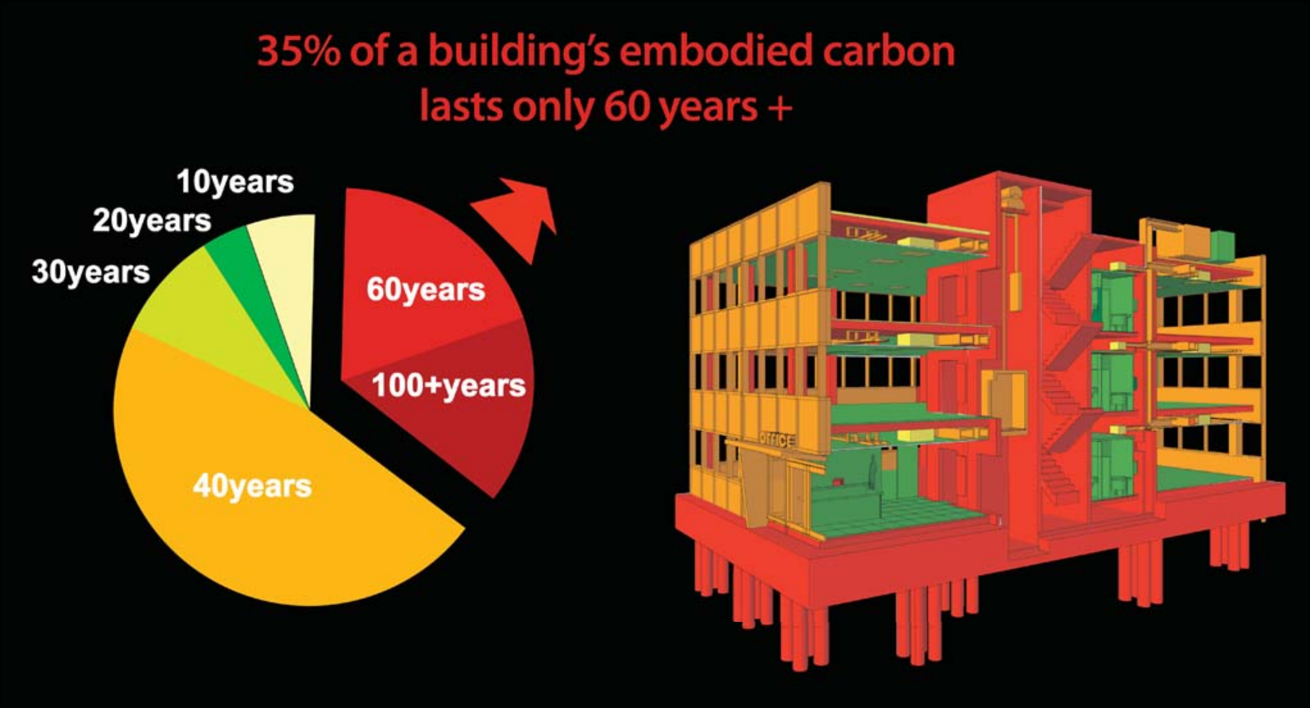
A few key areas exist that, if resolved at the initial design stages, can have a great effect on a building's durability, longevity, value and overall carbon performance. The main targets are sourcing, layering, methods of fixing, and the location of building performance layers. Getting these right is not necessarily complex, but can be achieved through the application of well co-ordinated design practice by bearing these issues in mind. With appropriate consideration of these issues it is possible to increase building lifespan, ease maintenance and therefore reduce carbon usage. The work of Philip Crowther[20] in particular highlights the need to address what happens to a building at the end of its life. Often these measures generate significant carbon savings that can be achieved at little additional build cost if incorporated into the design process early enough.

After construction some of the factors that are often the cause of higher than anticipated carbon emissions for a building once it becomes occupied may be attributed to quite simple sources that may be easily rectified, and without large capital expenditures. For example:

- **Operational Emissions**
  - Mismanagement of plant
  - Poor maintenance of plant
  - Occupier Culture
  - Incorrect sizing of plant for occupiers
  - Poor airtightness – maintaining seals on windows and doors.
- **Embodied Emissions**
  - Lack of thought about maintenance / phased replacement
  - Lifespan not considered or reconciled with use patterns
  - Badly detailed weathering junctions
  - Damage to building control layers during maintenance / refurbishment.
  - Failing to store building materials correctly on site before their use.

Figure 26 shows the relative lifespans of built fabric as percentages of total construction spending. The following on figures 27-30 indicate some of the key areas to focus on to deliver low carbon efficient buildings.

Figure 26 The majority of building components have a short life



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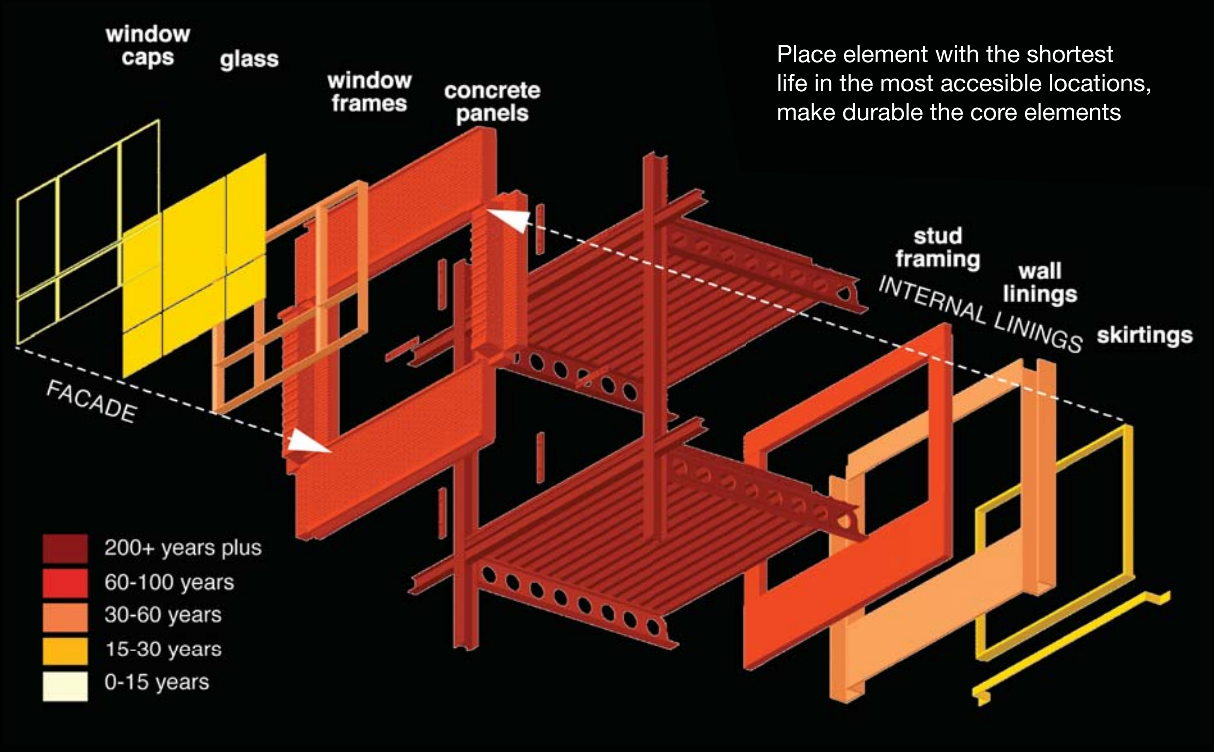
[20] *Crowther, P., 1999. Design for Disassembly to Recover Embodied Energy. In: The 16th International Conference on Passive and Low Energy Architecture, 22-24 September 1999, Melbourne, Brisbane, Cairns.*

Appendix 1

Figure 27 Age layering of components



Place element with the shortest life in the most accesible locations, make durable the core elements

Figure 28 Sourcing of original components

Identify economically viable replacements for virgin sourced materials

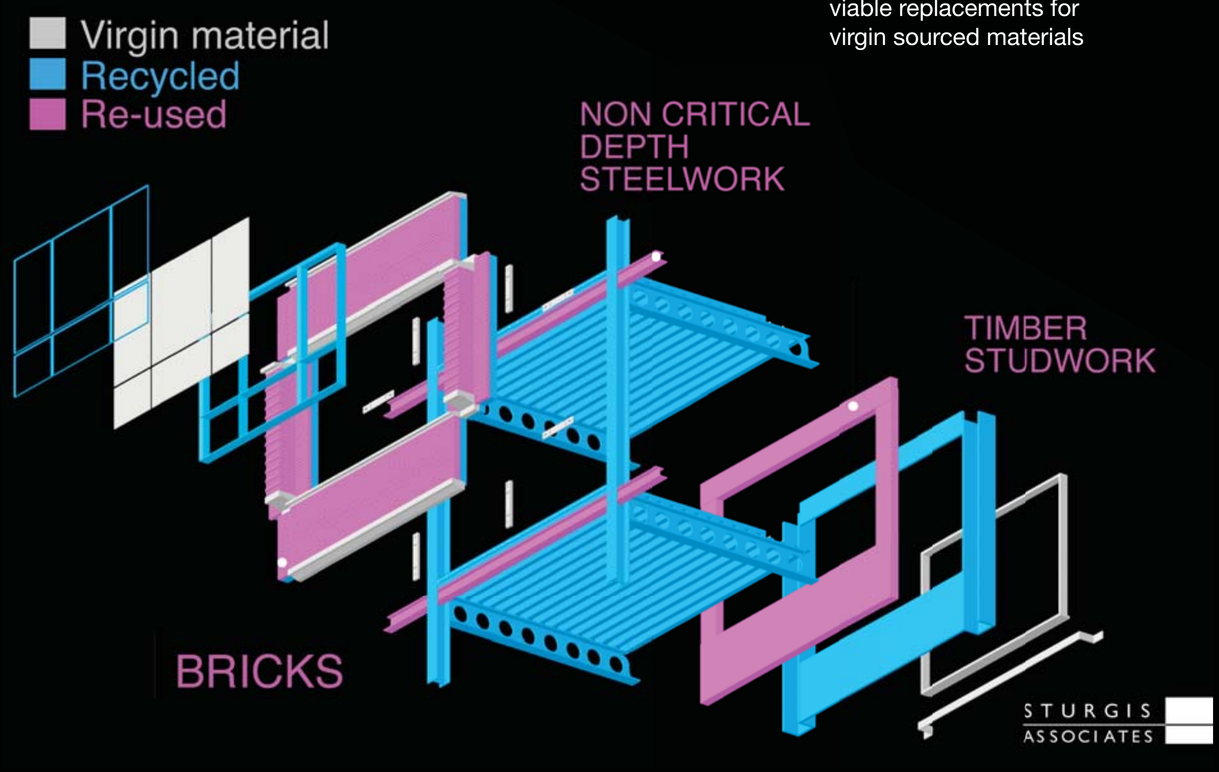
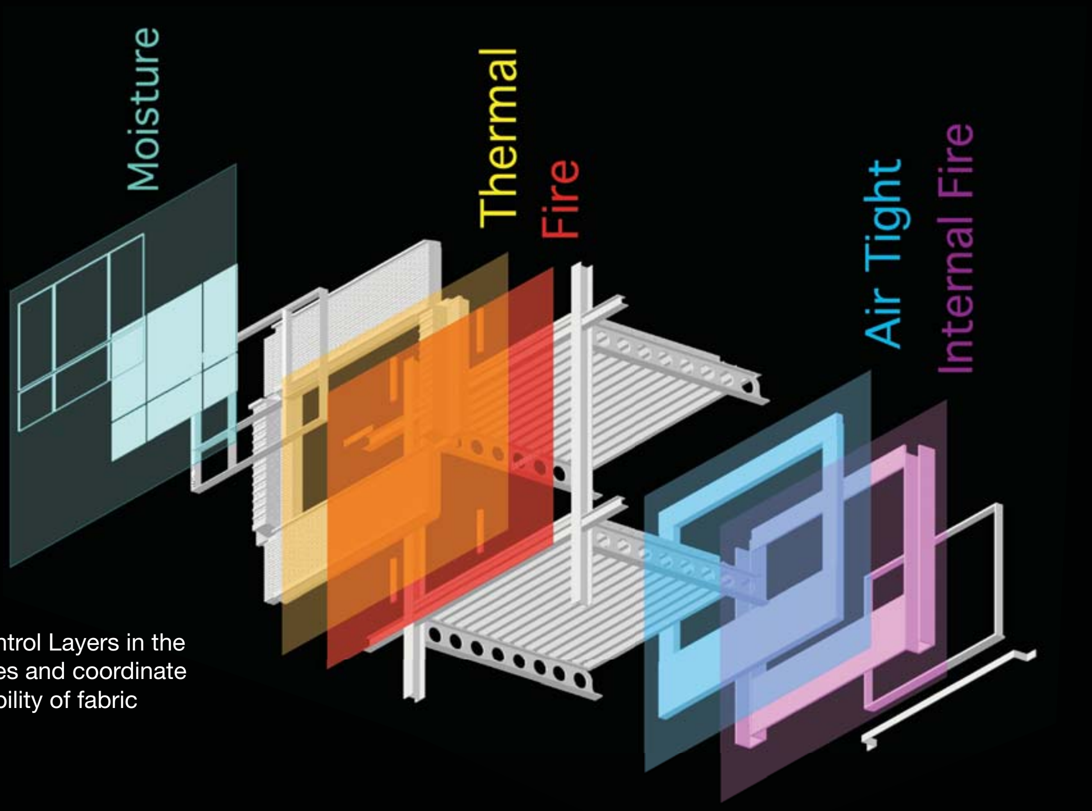
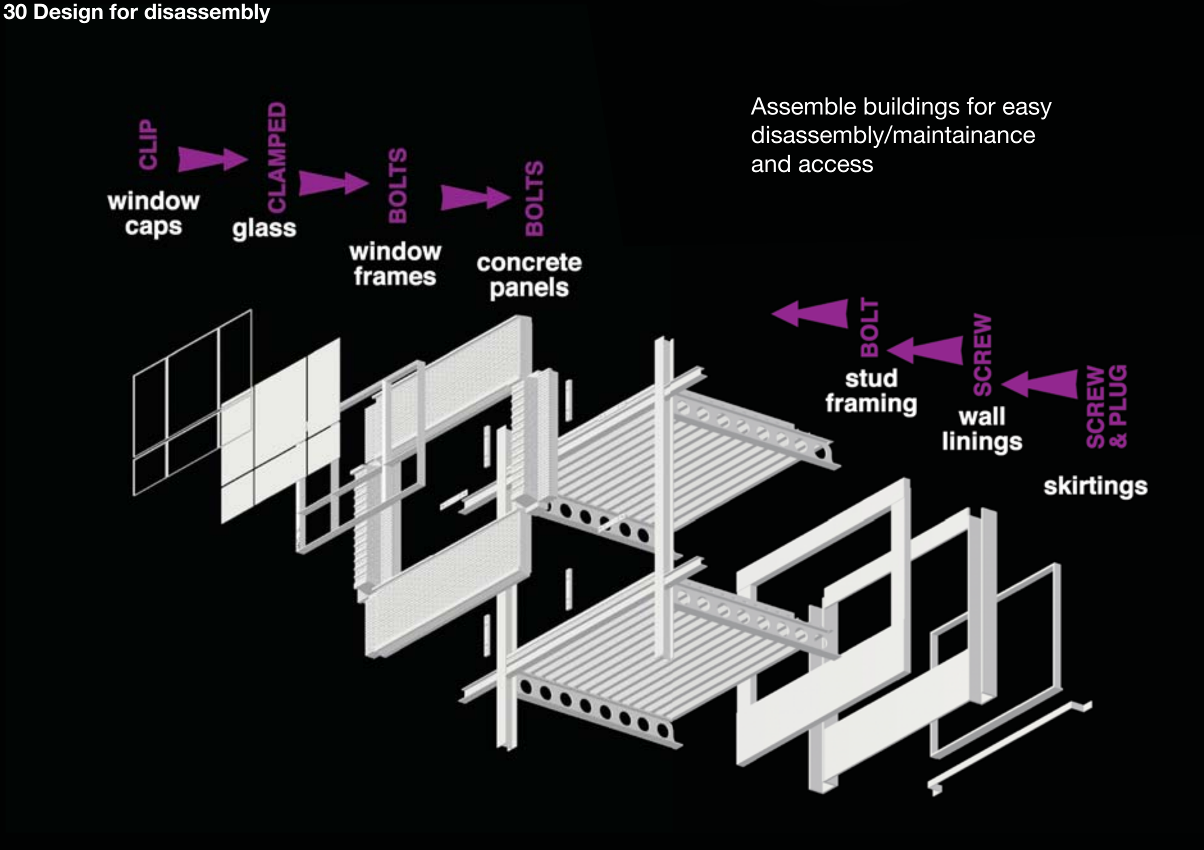


Figure 29 Location of building performance layers



Install Control Layers in the right places and coordinate with durability of fabric

Figure 30 Design for disassembly



Assemble buildings for easy disassembly/maintainance and access

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RICS has a worldwide network. For further information simply contact the relevant RICS office or our Contact Centre.

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