Towards a sustainable construction practice

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ABSTRACT

This paper outlines the challenges the construction industry is currently facing in order to meet the requirements of the new codes and standards introduced by Government to reduce carbon emissions of buildings. It argues that tackling environmental sustainability alone is not enough and that a holistic approach should be sought by addressing all three principles of sustainable development namely social, economic and environmental. Three research questions are addressed; why sustainable buildings are required, what defines a sustainable building, and how they can be obtained. The paper emphasizes on the necessity of a holistic approach relying on the collaboration of all stakeholders to quantify and interpret emissions throughout the building lifecycle as a key indicator of responsible use of resources and energy.

KEYWORDS: Sustainable Design and Construction, Renewable Energies, Embodied and In-Use Energy, Whole Life Cycle Analysis

INTRODUCTION

It is now widely accepted that the construction industry is a major contributor to climate change, as it is responsible for almost half of the global greenhouse gases and consumes 40% of the materials entering the global economy (Asif, Muneer and Kelly, 2007). The DTI (DTI 2006) reports that the global greenhouse gas emissions increased more than four-fold in the last half of the twentieth century. As worldwide population grows and hence more buildings will be needed, one may assume that the construction industry will continue to increase its carbon dioxide emissions unless it changes its practice.

In the UK, our dependence on fossil fuels and Government emphasis on meeting reduction targets has focused interest on methodology for carbon footprinting building products and buildings. The effect of CO_2 on Climate Change can arguably be seen as the greatest impact and therefore of the most urgent priority. In response to the challenge of climate change, the UK has introduced some ambitious codes and standards including the Code for Sustainable Homes (Department for Communities and Local Government, 2007) in order to reduce the energy requirement of buildings with a view to make them zero carbon in the future. This not only has generated a lively debate about how practical and realistic these targets may be, it has also raised the question of whether placing priority on one criteria of green house gas (GHG) emissions will address environmental sustainability. Further to this failing to consider the economic and social context is likely to frustrate any attempts to achieve a realistic level of sustainable development (Hyde, 2007). There is also an emerging school of thought that sustainable development has to be expanded beyond the construction industry by arguing that green buildings alone may be insignificant in the wider scheme (Sell, 2007) and that to make sustainable design and construction practices worthwhile there must be balanced priorities between the construction industry, the community, individuals and the local and national government. Buildings are not just about architecture or the construction industry; all stakeholders have a part to play in their sustainability in the longer term.

The aim of this paper is to demonstrate that a holistic approach must be taken to the analysis of green house gas emissions from the built environment. Three significant research questions - Why do we want sustainable buildings? What defines a sustainable building? How can we get sustainable buildings? - are answered in brief by the following objectives;

1. To identify the drivers for sustainability
2. To identify the content for sustainable buildings
3. To identify the process for development of sustainable building

The paper concludes on the necessity of a holistic approach relying on the collaboration of all stakeholders to quantify and interpret emissions throughout the building lifecycle as a key indicator of responsible use of resources and energy.

Sustainability drivers: Why do we want sustainable buildings?

It is now widely accepted that tackling environmental sustainability alone is not enough and that a holistic approach should be sought by addressing all three principles of sustainable development namely social, economic and environmental. In the UK, in 1999 the Department of Environment, Transport and Regions (DETR) defined sustainability as social progress which recognises the needs of everyone while provide effective protection of the environment by prudent use of natural recourses ensuring maintenance of high and stable levels of economic growth and employment (Mawhinney, 2002). This requires a change in lifestyle (Hale and Lachowicz, 1998) as, for example, living in a low energy house but having large carbon footprints for other daily activities such as transport, food, waste and infrastructure will result in an unsustainable pattern of living. Wines (2000) argues that most people approve of the changes prescribed by environmental reforms as long as they do not result in changes in lifestyle or have an impact on quality of life.

Table 1 *Building Emissions Standards*

	Measure	2002	2006	2010	2013	2016	2019
Domestic	**$KgCO_2/m^2$** AD Part L1 (2006)	0%	22%	25%	44%	100%	
	General sustainability Code for Sustainable Homes	NA	Level 0-1	Level 3	Level 4	Level 6	Level 6
Non domestic	**$KgCO_2/m^2$** AD Part L2 (2006)	0%	Up to 28%	35%	40%		
	Energy performance certificate equivalent rating	NA	Equivalent to D/C	C	B	B	A

Addressing all drivers of sustainability is outside the scope of this paper; here the focus is on GHG emissions from all parts of the lifecycle of buildings. The Government has introduced measures for the progressive tightening of building regulations (AD Part L 2006) in 2010 and 2013 for both domestic and non-domestic sectors, with the aim of achieving Zero Carbon new homes by 2016 with the requirement for all new homes to meet the Code for Sustainable Homes level 6. The term zero carbon in this context means that the net carbon emissions from all energy use would be zero (Department for Communities and Local Government, 2007). Table 1 illustrates equivalent energy/carbon standard in the code compared to Part L Building Regulations, Code for Sustainable Homes and Energy performance Certificates.

The Code for Sustainable Homes is currently only applicable to new buildings. The Building and Social Housing Federation (BSHF, 2008) argues that carbon abatement in existing buildings must also be targeted based on the fact that new houses comprise only about 1% of the total building stock at any one time and similar levels of energy efficiency can be achieved with quality refurbishment. A house built in the 1930s typically produces 4.7 tonnes of CO_2 for annual space heating (Smith, 2001) compared with 0.6 tonnes for an AECB Gold standard home (AECB, 2008). Eco-refurbishment of existing buildings is therefore of crucial priority as it results in enormous energy savings and will create job opportunities for the industry. The Existing Homes Alliance has recently proposed that half a million houses should be eco-refurbished during the next five years as this will save carbon, create jobs, stimulate new business opportunities and reduce energy bills (Clark, 2008). It is critical that home owners and private landlords address energy efficiency in existing housing stock. SAP ratings and Energy Performance Certificates at sale and letting may help to promote the issue of fuel cost differential between properties, but where a change of occupant is not frequent improvements are less likely to be made.

The UKGBC Measuring and Reporting task force recently published their first report on defining Zero Carbon (UKGBC, 2008). This report raised the issue that under the UK governments plan to reduce GHG emissions by 60% by 2050, a commitment has been made to ensure that all new housing is Zero Carbon by 2016 and all new building are zero carbon by 2019. This is a target that cannot be attained with the current national grid dependency on fossil fuels and technological advances are not available to ensure that buildings can achieve this stringent standard. An alternative to this position could be adopted by the UK in the lifecycle approach to emission management, considering the initial impact, and end of life alongside operational emissions.

For the UK to have an effective reduction in GHG emissions from buildings there must be a co-coordinated approach involving all stake holders including the client, the industry and local authorities and government. There is a need for building users (clients) to be involved in the design in order to identify their needs and goals otherwise it will be difficult to judge which of energy saving concepts and measures perform well and which do not work at all (Ford et al 2007). Hyde (Hyde, 2007) highlights the risk of buildings users to become alienated through the design process if the only concern is to meet zero carbon targets. Edwards and Hyett (Edwards & Hyett, 2001) argue that social inclusion and energy-efficiency must come together closely in the area of housing and warn that sustainable housing is often presented purely as an exercise in low energy design without addressing the need for creating sustainable communities. Helweg-Larsen and Bull (Helweg-Larsen & Bull, 2007) emphasize that the best strategy is by seeking a balance between social, economic and environmental factors at a local level and applying energy targets to buildings by region or area.

CONTENT: WHAT DEFINES SUSTAINABLE BUILDINGS?

Once we have determined that sustainability has a significant place in the building brief it is necessary to measure the success of the design. Market forces and legislation are working together to force or leverage change towards more sustainable practices in the construction industry. Legislation raises the lower benchmark whilst market forces raise the upper benchmark. How to demonstrate the success of the sustainable building remains a challenge to the client and their design team and they must chose from a range of options.

Using Subjective Assessment Models

In the commercial world, competition is emerging as the most effect driver for change. For example, the main supermarkets in the UK are actively pursuing the first zero carbon stores. Validity of claims may be called into question in areas not effectively covered by assessment routes such as SBEM and BREEAM. Sustainable initiatives also have a role to play in the marketing strategy of domestic and commercial buildings.

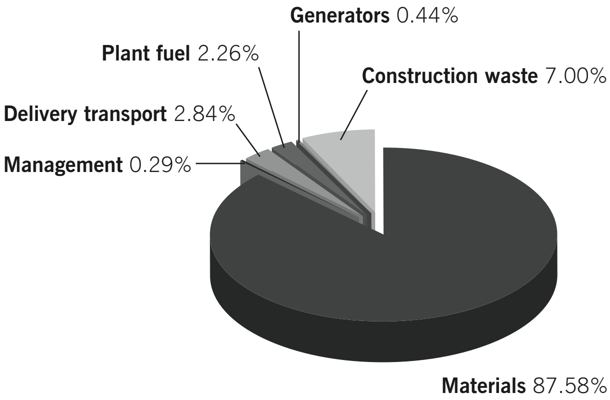
The Building Research Establishment Environmental Assessment Method (BREEAM) has provided a benchmark for a range of building types in the UK. Residential buildings were voluntarily assessed using Ecohomes until the Code for Sustainable Homes was introduced in 2007 (BREEAM, 2008). New rating of Outstanding is being introduced in 2008 (BREEAM, 2008) to further reward the best examples. The credibility of both these standards is the assessment being carried out by environmental consultants trained and accredited by the BRE with validation of all assessments. The cost of assessment remains a significant barrier to uptake in small projects and leads developers to only undertake pre-assessment advice but not a full assessment to save on assessment costs whilst still improving the building. The BREEAM mechanism is sufficiently transparent to use as the basis for design briefing and benchmark setting by the project design team without commitment being made by the client for assessment. However, the project team does not then benefit from the experience and guidance offered towards improving the building during the assessment process.

Using Objective Assessment Methods

Calculating whole life emissions or lifecycle analysis of multiple characterised impacts can provide a robust assessment of the environmental impact of a building. The BRE have developed methodology for life cycle analysis which provides characterised impact data for materials and products, this is also normalised to provide Green Guide Ratings which are used as part of the BREEAM assessment and Code for Sustainable Homes. Calculating the sum of all of the green house gas impact helps to promote efficient use of materials and may promote low carbon construction techniques more effectively than LCA because of the greater simplicity of analysis at the point of practice. Life cycle analysis can often demonstrate a wide variety of pollution impacts. However a simpler method is to utilise the Green Guide (BRE, 2008b) to Specification Product Profiles, providing it is not needed to aid in design decision making between characterised data profiles for products. This data is protected by both the Construction Products Association and the Building Research Establishment. In a building project material selection is a function of a number of decisions; thermal performance, lifecycle impact, cost, maintenance, carbon impact, health and safety implication, delivery implications, availability and programme implications and aesthetics. Prioritisation or ranking of these attributes must be established between the client and the design team and are dictated by the building type, budget, and when it must be completed and how and by whom it will be operated, but external factors may also be relevant such as planning restrictions or requirements made by funding authorities and insurers.

Calculating emissions from the construction process is a relatively new concern for the construction industry and published sources are limited. Monitoring of fuel use, water and transport on site carried out for BREEAM assessment can provide data with which to calculate the impact of the construction of buildings. The example in Figure 1 was generated for a very large distribution centre using data collected on site for BREEAM assessment (Fieldson and Smith, 2007). The manufacture of materials is the largest contributor to this impact; comparisons of similar buildings constructed by different contractors demonstrate that materials are a major impact of around 90% (Fieldson and Siantonas, 2008).

Figure 1 *Emissions from construction of a Distribution Centre*



The conventional view is that in-use emissions are far more significant than embodied emissions, and that is certainly true for many existing buildings. New buildings constructed to current Building Regulations AD Part L 2006 and better will have a higher ratio of embodied emissions to operational, and this situation will only become more acute as both domestic and non-domestic buildings are designed to meet zero carbon (Fieldson and Smith, 2007). Even where buildings are designed to be zero carbon in use and attempt to have low embodied emissions by substituting alternative materials such as replacing cement with lime, embodied emissions remain significant (Sodagar et al 2007a; Sodagar et al 2008a). Re-using older building stock and upgrading to current standards or better would reduce the emissions in comparison to new build. This has been demonstrated in domestic building stock (BHSF, 2008), and also in office design (Sodagar et al 2008b). The impact of designing a building from transport of consultants to meetings and its impact in terms of waste and recycling deconstruction must also be considered (Equation 1). Calculating the entire impact of the building gives a better representation of the scale of the impact than focusing on savings achieved by adopting a specific elemental choice.

Equation 1 *Calculating Whole life Carbon Emissions (Fieldson and Smith 2007)*

Design Stage PMc	Materials Ec	Construction Cc	Operation Rc	Deconstruction Dc

Whole life carbon emissions

Whole Life Emissions (WLE) = PMc + Ec + Cc + Rc + Dc

Where:

PMc Project Management carbon; the off-site carbon cost of designing and managing the project, for example, customers, consultants, contractors

Ec Embodied carbon; the carbon input into the production and assembly of materials and components of a project

Cc Construction carbon; the carbon input required to deliver and assemble line components into a building including waste

Rc Running carbon; the carbon emissions associated with running the building over its design life, including maintenance and repair

Dc Deconstruction carbon; the carbon emissions associated with the removal of the building at the end of its working life.

The European Standards Committee (BERR 2007; Davies and McPherson 2008) is working on a normalised standard for Environmental Product Declarations for Buildings, which would better represent the huge environmental impact of building and demolishing buildings and also be a representation of the impacts relating to pollution and resource degradation as well as climate change. The CEN TC 350 standard once published may provide very clear guidance on the need to include impacts from the construction process in Environmental Product Declarations (EPD's). It will however require the provision of a publicly accessible UK database which is geographically relevant and up to date for the materials specified by the construction industry. This standard is not yet available for general viewing. Without such a database and considerable declaration of LCA findings by product and materials manufacturers it will be difficult for either comparative EPD's or to use LCA effectively in the design of buildings. Carbon Trust has developed a Supply Chain methodology (Murray, 2007) for carrying out such analysis on many levels.

The range of software utilising National Calculation Methodology (BRE, 2007b) available to help the design team to assess the energy use and comfort characteristics of a building design has increased rapidly with the introduction of AD Part L (2006). The building must firstly be proven to pass the minimum benchmark, and depending on the aspirations of the client exceed this minimum standard by a defined percentage. The relationship between modelled results and monitoring of buildings in use has been limited, and it would seem that many buildings turn out to behave differently than predicted because actual occupation and facilities management is not what was originally anticipated. They are only as good as the data put into the model, and where the data is limited or inappropriate substitutions are made, the information may have very limited value to the designer or the facilities manger in terms of predicting actual energy use. How to incorporate these tools into the design of a building is often a matter of cost and time acceptable for the level of sophistication of the building and the tool required to make adequate testing of the design.

It is clear that no single method or tool of defining a sustainable building is more appropriate and that a combination of these methods must be employed to ensure that the building can offer the best facility to the end user in terms of economy and usability and minimise social and environmental impact.

PROCESS: HOW DO WE GET SUSTAINABLE BUILDINGS?

Theory for making a sustainable building is helpful, but the realities of the construction industry and constraining forces can erode high principles. These can be seen as barriers but this is a negative approach, if we seek to fully understand the issues from the viewpoint of all of the stakeholders and the challenges they face it becomes easier to have successful outcomes.

Edwards and Hyett (Edwards and Hyett, 2001) argue that although architecture alone can not solve global environmental problems but it can make a significant contribution to the creation of more sustainable habitats. One obstacle to the wide uptake of low energy design is the extra cost such buildings may incur and who should actually pay for it; financiers, developers, or occupiers? Although large developers may be able to readjust their business to accommodate the extra costs, it is usually difficult for marginal developers to do so. To overcome this barrier, there should be financial incentive in place and also innovative fiscal arrangement so that for example the extra cost may be provided up front by financial institutions and claimed back later, for example through increased rents. It may therefore be argued that the best way to harmonise environmental protection and economical development is to bring environmental costs and benefits right to the heart of economic decision making (Hale and Lachowicz, 1998).

Sustainable Clientship

The client or developer is the determining factor in the sustainability achieved by any project. They must show leadership to their design and procurement team and force innovation through their supply chain to provide more efficient, less polluting and cheaper buildings. This also requires managing the project in such a way as to promote good use of human resource and knowledge and the respect of the client for the values of the organisations it involves in building procurement alongside clear definition of its own values. This is a necessary part of the briefing process for a building; the design team must understand the client's budget, programme, functional requirements and corporate responsibility values to ensure that the building performs. Some developers may take the decision to absorb the additional cost of a sustainable design brief and use this demonstration of pro-activity as a marketing tool (Gazeley, 2008).

Client can choose where to position themselves upon the scale shown in Figure 2. This profundity of effort requires putting pressure against resistance to change in building parameters such as increasing cost and complexity and difficulty in obtaining funding or planning permission. This will be a defining factor in how they select their design and procurement team and how they formulate benchmarks for the performance of the building. The strategy they take towards moving from one level on this scale to the next will also determine the way their buildings develop and improve their sustainability over time.

Figure 2 *Profundity of effort (Fieldson, 2007)*

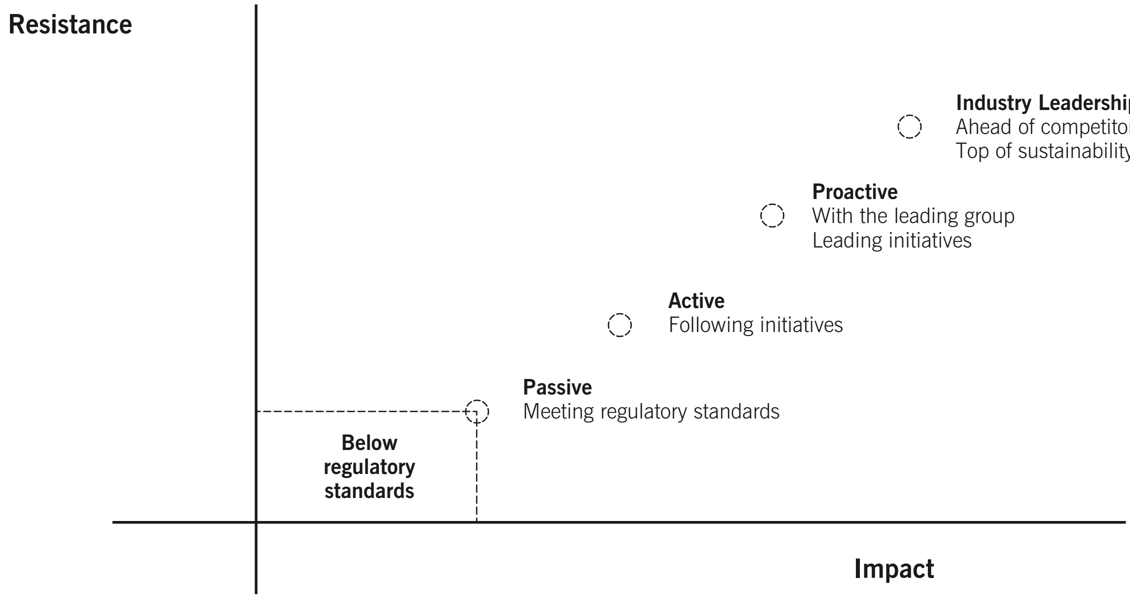
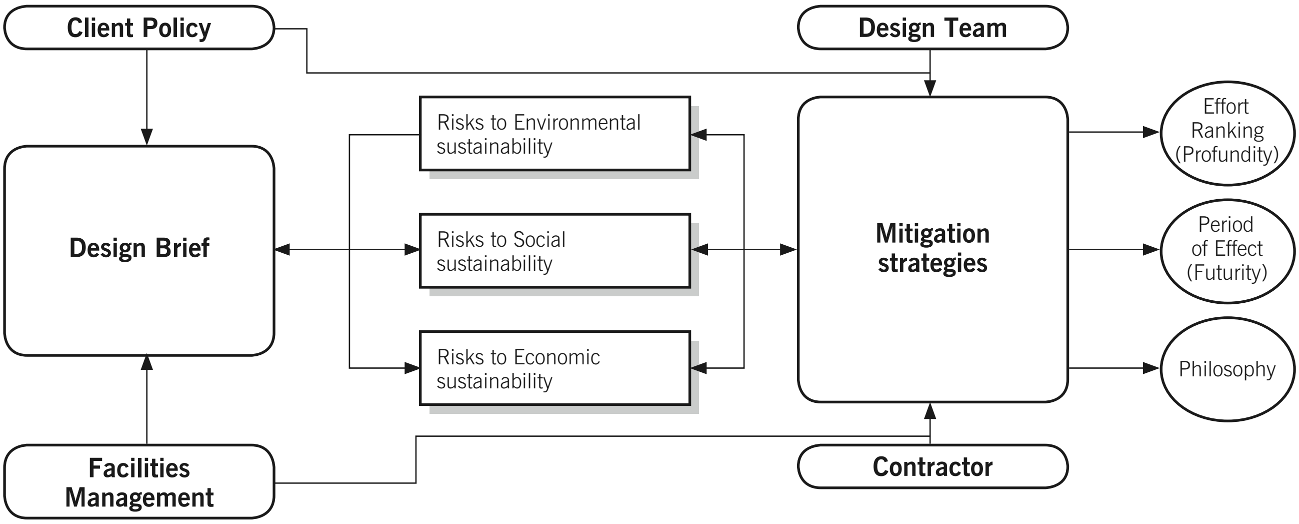


Figure 3 *Sustainability Risk Management procedure (Fieldson, 2007)*



Risk to sustainability may also be used to develop the project brief. By assessing how the proposed building will impact on environmental, social and economic sustainability, targets and mitigating strategies can be developed which can stay as a document with the building as a guide to facilities managers in use and through to refurbishment or end of life (Fieldson, 2007). *Figure 3* provides a process diagram for the analysis of sustainability risk posed by a project.

Sustainable Design

Defining sustainable design as a philosophy will help to understand and identify the most appropriate design strategies which if applied to all aspects of design from inspection to completion should maximise quality and minimise impact (Sodagar et al 2007a). Different terms are being used for sustainable design including 'green architecture' 'climate responsive architecture', 'high-performance' and similar terms (Kibert, 2005). Kibert concludes that all have one key objective; to apply principles through the entire life cycle of construction, from planning to disposal. Some authors are radical in their views about the function of sustainable design by giving absolute priority to the environmental performance by arguing that sustainable buildings are not about fashion or style but about performance (Roaf et al 2004). Edwards and Hyett (Edwards and Hyett, 2001) argue that in spite of recent development in low energy technologies the industry has not yet put sustainability at the heart of its operations. This view is supported by Guy and Moore (Guy and Moore, 2005) who argue that the industry tend, for commercial reasons, to follow the minimum legal requirements when designing and building homes. The increasing demand on teaching sustainable design to architecture students imposed by Royal Institute of British Architects (RIBA) and Architects Registration Board (ARB) is the right step towards promoting the uptake of sustainability by the profession. An integrated approach to teaching design and sustainability has demonstrated its effectiveness in encouraging students to turn their understanding of environmental design into action (Sodagar et al 2007b).

Another obstacle to sustainable design is that there are architects who are not concerned with green architecture as they believe that energy efficiency and architectural aesthetic are two conflicting elements and are wary that the label of green architect may affect their public perception (Stang and Hawthorne, 2005). There are good proofs both in the UK and globally suggesting that it is possible to design and build buildings which are while energy efficient they are aesthetically pleasing. It is a priority for the design community to demonstrate through good pieces of architecture that energy efficiency and aesthetic are compatible and not conflicting.

Life cycle thinking is a conceptual aid to design and building management which allows the full lifespan of the building and particularly the end of life impact of a building to be considered in the decision-making process. This concept is important for the balancing of the effects of manufacturing, use and disposal of the many products within construction and also the entire construction itself. This is true for any impact and between impact boundaries. For example, a material may be low carbon in production but have a high social impact, have an important contribution to reducing running costs, but high pollution impact at the end of life because it cannot be recycled. The product has positive benefits and negative impacts, and the acceptability of its use must be balanced in the mind of the designer, and justified to the stakeholders of the building.

Sustainable Services Design

Renewable or low to zero carbon technologies (LZC) can provide a significant percentage of the energy required for buildings located in appropriate environments, where sunlight, wind and biofuels are plentiful. Many buildings, especially in cities can gain limited benefit from solar and wind power and biofuels could cause particulates air pollution therefore an alternative must be found. Many new and refurbishment commercial buildings have an opportunity to vastly improve energy efficiency through better use of airtight thermal construction, solar design and daylight management alongside flexibility of control and integration of services. Budget should always be targeted at maximizing efficiency before LZC technologies are incorporated as this has the largest potential to reduce the quantity of energy generation needed and cost to carbon saved ratios are more acceptable.
Design of renewable services systems should be carried out as part of the building form design and site layout, not as an afterthought or maximum generation capacity will not be achieved. Some building types such as mixed use retail, office and residential urban locations may be unable to achieve autonomy through renewable generation, but will be able to make an effective use of other mechanisms such as heat recovery or natural gas combined heat and power with absorption cooling to vastly reduce energy demands of building services.

Sustainable Cost Management

Research by BRE and Cyril Sweett (Cyril Sweett, 2005) suggest that the cost premium to achieve good practice as defined by BREEAM, are between 1 and 10%. Based on desk top studies carried by Davis Langdon, the estimated capital cost premiums of securing progressive reductions in carbon emissions over statutory minimums for different dwelling types as a result of a combination of fabric enhancement and

LZC may range from 1.7% to 12.7% (Rawlinson, 2008). Buildings are rarely developed without an agreed availability of funds which often are capped by some limit, by government budgets, grants and charitable funding or capital expenditure. If something is not deemed economic, it will not be instructed. Project managers would not want to accept the consequences of failing to manage their budget, or it might be that a vital functional element of the building would have to be sacrificed. A sustainable building which does not function well in terms of space, facilities or social accessibility will be as much of an environmental burden through lack of utilization as a well functioning building with a high operational carbon impact.

The very basic assessment requires the calculation of capital or initial cost with running cost/maintenance however the process is more complex requiring knowledge management alongside corporate responsibility evaluation to provide better decisions in cost evaluation for sustainability

Adding value through design is critical to any building which needs to attract customers to be successful, from visitor centres and museums to sports facilities and supermarkets. Public perception and interest in sustainability and the learning potential of visible renewable energy generation is important. Many other sustainability measures are less easy to see and must be communicated in other ways which may result in positive publicity. To really understand the benefits bestowed by good environmental design, long term studies of energy use, occupant health, happiness and productivity must be carried out.

Environmental design has a financial cost, and sometimes it has a social cost too. These costs must balance and be justified. In commercial construction, the cost of failing to address matters of sustainability can be embarrassing and costly in terms of prosecution, bad media coverage and loss of trade. Commercial stakeholders are being increasingly knowledgeable in environmental and ethical matters.

Making cost comparisons for a whole building can be time consuming and costly in term of design consultancy fees. It is necessary to develop two parallel schemes, one conventional “base build” specification and one with various initiatives included to meet the sustainability brief. This method of comparison can be very difficult to prove because the initiatives often need to be priced in isolation, where in reality they should work together. The client needs to take a leap of faith into the unknown with untried methods, new materials and possible facilities management implications to be wary of. It is easy to blame clients for reticence and detrimental frugality, but they often have a lot at stake. Finance is not so much a barrier to sustainability as lack of confidence, lack of education and fear of failure.

Whole life costing tends to be carried out at elemental level and will take into account savings in running costs between one and ten years. The prices of fuel used in calculations needs to take into account rising costs and has very likely not been representative in decisions made in recent years bearing in mind increases seen in the global price of oil in the last 12 months.

Another way to justify elements of environmental design is to calculate their carbon cost effectiveness in £/kgCO_2/m^2. This gives a good indication from a range of measures which is most beneficial, and which is of limited value. Other measures can be made such as litres of water saved (although this can also be given a financial value against supplied water). Using financial valuation based on the cost of fuel and electricity for pay back periods or carbon cost effectiveness can be criticized too. DEFRA have valued the social cost of carbon at £26.50 a tonne (Schoon, 2008), carbon off-sets can be purchased at far cheaper values and are not representative of the cost of effective reduction in real fossil fuel use. Valuing the social health of pollution and climate change can also be an effective decision making agent (Amato, 1996).

Sustainable Construction

Managing the construction process in a safe, efficient and effective way will usually save money and time, and much of this cost is related to fuel use and logistics. Employing modularisation and off-site construction methods to reduce performance uncertainties and risk of accidents on site has environmental benefits in terms of reducing waste of materials, transportation and can improve building performance in terms of air tightness and quality of finish too. The use of consolidation centres can save delivery frequency and protect materials from damage on site. Whilst the fuel used directly by the contractor is a small impact in the holistic approach, the skill used by the contractor in detailing and finishing the thermal envelope has a lasting impact on the operational efficiency of the building. Waste generated on site is a larger impact and all efforts should be directed towards limiting waste sent to landfill to an absolute minimum by employing strategies to ensure waste is firstly eliminated by design and specification co-ordination or ensuring a recipient is found either through a waste handler who can repackage or recycle the material for other uses or return to the supplier for reprocessing. Currently around 50% of construction waste is recycled and it is hoped that a further 50% reduction in waste arising form construction between 2008 and 2012 will be achieved (BERR, 2008). A number of tools are available to assess and predict waste quantities (WRAP, 2008: BRE, 2008; Greenspec, 2008), however the exact LCA impact arising from these is less easy to assess. Lengthy and complex construction projects can require sizable temporary office facilities, if these are well managed and arranged with good cabin design, considerable savings can be achieved (Speedyhire, 2008). Using mains to power construction works will result in a much reduced GHG impact (Fieldson et al 2008).

Sustainable Operation

Good well informed facilities management is critical to excellent building performance, post occupancy evaluation carried out regularly is vital, monitoring of services is necessary to ensure the building is operating as it was designed to and occupant surveying will help to establish comfort levels. There will be a limit to the successive energy savings an occupant can make over the design life of a building through careful management alone and there will be a need for additional investment from time to time. Maintenance and cleaning are vital to ensure a building continues to perform well. Excellent guidance for this procedure is provided by CIBSE (2008).

Sustainable Deconstruction

The end of life of any building should be extended to minimise environmental impact. If the expectation for the functional need for a building is short, a strategy should be in place from inception to identify or optimise secondary uses. If this is not possible then a well defined strategy for deconstruction should be established and communicated to building users and owners to facilitate deconstruction (Morgan and Stevenson, 2005; Addis and Schouten, 2004). Demolition should be replaced by Eco-deconstruction. The current practice of demolishing buildings is environmentally unacceptable and is not without its costs to the community as it is a practice based on speed and minimum cost resulting all materials ending up in landfill with few employment opportunities. There is a need for research and development to offer innovative solutions for design for disassembly and eco-deconstruction.

CONCLUSIONS

The move to zero carbon buildings has created a lively debate on the practicality of the proposed codes and standards and has resulted in an unprecedented level of awareness in the building industry about the actions required to tackle climate change. It is now expected that operational energy efficiency will be leveraged in order to meet the carbon targets set by Government. It is of crucial importance for all stakeholders to realise that sustainable development is not only about energy efficiency in use. A balanced view should be sought to address all aspects of sustainability namely social, economic and environmental sustainability. This not only requires a change in the way we design and build and deconstruct, it requires a change in life style in order to reduce our ecological impact to a level the earth is capable of supporting. There is a need to address existing building stock as eco-refurbishment will play a major role in reducing UK emissions from construction materials. In order to design a truly sustainable and innovative building, the design team requires having access to best available data and information on products and materials to support decision making in the design process. The construction industry must support this by providing robust data collection of the content and process of completed building. This will only be achieved by the construction industry working together towards a common goal of reducing UK emissions at the fastest pace possible whilst maintaining social and economic sustainability.

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