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Designing low carbon buildings: A framework to reduce energy consumption and embed the use of renewables

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ABSTRACT

EU policies to mitigate climate change set ambitious goals for energy and carbon reduction for the built environment. In order meet and even exceed the EU targets the UK Government's Climate Change Act 2008 sets a target to reduce greenhouse gas emissions in the UK by at least 80% from 1990 levels by 2050. To support these targets the UK government also aims to ensure that 20% of the UK's electricity is supplied from renewable sources by 2020. This article presents a design framework and a set of integrated IT tools to enable an analysis of the energy performance of building designs, including consideration of active and passive renewable energy technologies, when the opportunity to substantially improve the whole life-cycle energy performance of those designs is still open. To ensure a good fit with current architectural practices the design framework is integrated with the Royal Institute of British Architects (RIBA) key stages, which is the most widely used framework for the delivery of construction projects. The main aims of this article are to illustrate the need for new approaches to support low carbon building design that can be integrated into current architectural practice, to present the design framework developed in this research and illustrate its application in a case study.

1. Introduction

European policies to mitigate climate change set ambitious goals for energy and carbon reduction from the built environment (European Commission, 2008). In order meet and even exceed the EU targets UK Government's Climate Change Act 2008 sets a target to reduce greenhouse gas emissions in the UK by at least 80% from 1990 levels by 2050 (Department of Energy, 2011). To support these targets the UK Government also aims to ensure that 20% of the UK's electricity supply is from renewable sources by 2020 (Department of Energy, 2011). Unsurprisingly given the ambitious goals for both carbon reduction and renewable energy generation the Government has introduced many different policies to support both an improvement in the quality of the UKs' building stock and the use of renewable energy technologies. For example, part L of the Building Regulations, introduced in 2006, imposes new requirements aimed at improving the energy efficiency of the domestic and non domestic building stock. A renewable energy scheme to encourage homeowners to use active renewable energy technologies, such as solar panels, has also been established (Department of Trade & Industry, 2007). In addition a number of measures to encourage the use of renewable energy in the commercial sector, some punitive and some encouraging, have been initiated. For example, Enhanced Capital Allowances (ECAs) enable a business to claim 100% of first-year capital allowances on their spending on qualifying plant and machinery (Energy Capital Allowance, 2010). The recognition of the need for carbon reduction from the built environment, along with new EU directives, more stringent building regulations and general environmental concerns, is also encouraging the development and application of sustainable building codes. In the UK these include the Standard Assessment Procedure (SAP) and the Simplified Building Energy Model (SBEM), the Code for Sustainable Homes (CSH) and the Building Research Establishment Environmental Assessment Model (BREEAM).

Against this backdrop of European and UK carbon reduction targets, policies, regulations and codes to support, renewable energy generation and carbon reduction, this article presents a framework and a set of integrated IT tools to enable an analysis of the energy performance of building designs. These tools and methods have been developed to support low carbon building designs which reduce energy consumption and increase the use of renewable energy technologies. It is essential that the framework supports design decisions made early in the design process before investment decisions are finalised and applications for planning permission are made. This is because many of these decisions, such as, building orientation, building shape, use of renewable resources and glazing ratios etc., have a huge impact on the energy performance of a building and are usually impossible to change during

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the later stages of the design process (Loh, Crosbie, Dawood, & Dean, 2010; Olofsson et al., 2011; Schlueter & Thesseling, 2009). In particular the use of both passive and active renewable energy technologies have a significant impact on a buildings energy performance, as well as impacting on building emissions rates, build cost and the application of regulatory frameworks (National Institute of Building Sciences, 2010). Given the importance of the decisions made during the early stages of building design it is surprising that energy assessments are not usually conducted until the later stages of building design. Currently these are predominantly limited to sizing HVAC systems and ensuring compliance with building regulations once planning permission has been granted (Crosbie, Dawood, & Dean, 2010; European Commission, 2008).

One of the main goals of the research presented in this article is to move consideration of the issues related to energy performance and sustainability to the earlier stages of building design process when the opportunity to significantly improve the energy performance of a building design is still open. To achieve this it is essential that new approaches to support sustainable design are integrated with current architectural business practice. To ensure a good fit with current business practices the framework presented is informed by interviews with professionals working for architectural companies. This approached lead to the integration of the framework with the Royal Institute of British Architects (RIBA) key stages, which is the most widely used framework for the delivery of construction projects within the UK and elsewhere (McElroy, 2009).

In essence the framework presented aims to integrate existing technologies and sustainable building codes to bridge the gaps in current approaches to low carbon design. This includes the integration of;

- Energy simulation tools and approaches for the analysis of building energy performance including estimations of the potential of active renewable energy technologies,
- National Calculation Methods (NCM) and codes to support energy efficient and sustainable buildings,
- Multi-Criteria Decision-Making (MCDM) approaches and tools designed to support stakeholder decision making in the building design process.

The framework is developed so that an architect can iteratively re-design a building and immediately see if the air pollutant emissions, energy consumption, or operating costs, have been reduced or increased by different design options. This ensures that designers, clients and stakeholders have the relevant information required for an assessment of cost versus environmental impact with regard to different aspects of a building's design. In this way building owners and users will have the opportunity to minimise operating costs and optimise performance over the building's lifetime.

The remainder of this article is divided into three sections. The first, illustrates the need for new methodologies and integrated tools to support sustainable design by presenting a review of building energy simulation tools, sustainable building codes and their application in current design practice. The next section then goes on to outline the design framework developed in this research to support the integration of the design methods and tools required for sustainable design practice into current architectural business practices. The third section presents a case study to illustrate how the framework can be used in a low carbon design process. The fourth and final section discusses the research findings, draws some conclusions and presents the future research avenues these conclusions suggest.

2. Gaps in current approaches to building design

2.1. Building energy simulation tools and their application

Building energy simulations are conducted by design professionals (architects, engineers and energy consultants etc.) using building design and energy analysis software tools to analyse the energy performance of their designs. For example, the energy performance feedback provided by whole building energy analysis tools allows designers to assure equipment is properly sized for the design conditions of a given building and that the part-load performance of buildings' subsystems provide a comfortable environment (Jacobs & Henderson, 2002). A database developed by the U.S. Department of Energy (DoE) currently lists almost four hundred energy tools designed to simulate the energy performance of buildings and/or their components (US Department of Energy, 2011). Many of these building simulation tools are designed to be used during different phases of the building design lifecycle and have different functionalities. For example, some whole-building simulation tools are capable of simulating the use of the most common active renewable energy technologies, such as, wind turbines and photo voltaic (PV) panels and some support selected National Calculation Methods (NCM) and codes for sustainable buildings. See Table 1, which presents a selection of widely used whole building simulation software highlighting the differences in their functionalities. There are also some stand alone tools to assess the effectiveness of the most common active renewable energy technologies at the building level, see Table 2, which presents a selection of the tools available and details their geographic applicability and output.

Table 1
Comparison of the functionality of whole building energy simulation tools.

Tool attributes	SBEM[a]	IES-VE v6.1[b]	TAS[c]	Design builder[d]
Integrated with BIM	N	Y	N	Y
Dynamic simulations	N	Y	Y	Y
Consideration of internal shading	Y	Y	Y	Y
Consideration of external shading	N	Y	Y	Y
Geometry/graphic approach	N	Y	Y	Y
Unlimited orientations	N	Y	Y	Y
Renewable technologies	N	Y	Y	N
Global climate data	N	Y	Y	Y
Calculation of natural ventilation	N	Y	Y	N
Building regulation Part L	Y	Y	Y	Y
Easy to use	N	Y	N	Y
Construction cost	N	Y	N	N

[a] SBEM, Simplified Building Energy Model, v3.5.b, 2011, http://www.ncm.bre.co.uk/.
[b] IES-VE, Integrated Environmental Solutions, v6.1, 2011, http://www.iesve.com.
[c] TAS Software, Environmental Design Solutions Limited (EDSL), v9.1.4.1, 2010, http://www.edsl.net/main/Software.aspx.
[d] Designbuilder software, v2.4, 2010, http://www.designbuilder.co.uk.