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Development of a methodology for life cycle building energy ratings

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ABSTRACT

Traditionally the majority of building energy use has been linked to its operation (heating, cooling, lighting, etc.), and much attention has been directed to reduce this energy use through technical innovation, regulatory control and assessed through a wide range of rating methods. However buildings generally employ an increasing amount of materials and systems to reduce the energy use in operation, and energy embodied in these can constitute an important part of the building's life cycle energy use. For buildings with 'zero-energy' use in operation the embodied energy is indeed the only life cycle energy use. This is not addressed by current building energy assessment and rating methods.

This paper proposes a methodology to extend building energy assessment and rating methods accounting for embodied energy of building components and systems. The methodology is applied to the EU Building Energy Rating method and, as an illustration, as implemented in Irish domestic buildings. A case study dwelling is used to illustrate the importance of embodied energy on life cycle energy performance, particularly relevant when energy use in operation tends to zero. The use of the Net Energy Ratio as an indicator to select appropriate building improvement measures is also presented and discussed.

1. Introduction

The energy use related to building operation activities such as heating, cooling, lighting, appliances, etc. accounts for about one-fifth of the world's total delivered energy (U.S. Energy Information Administration, 2010).

Building energy regulations and standards, which were widely adopted after the 1970s oil crisis, generally focused on limiting heat transmission values of construction elements, which served as a good first approach to reduce energy use for space conditioning. Regulations have evolved over the years and now generally include detailed assessment and methods of building energy use. Building energy certification and rating schemes based on calculated energy use are very common and often mandatory in regions such as Europe. There is also a progressive approach towards regulating for low energy and 'zero energy buildings' as expressed, for example, in the International Energy Agency policy recommendations on energy efficiency as issued to the G8 (Jollands et al., 2010). Many countries have established strategies towards 'low energy' or 'zero energy' buildings, as compiled by Thomsen and Wittchen (2008), and key regulatory schemes such as the recast of the European Energy Performance of Buildings Directive (EPBD) (European Parliament And The Council Of The Europen Union, 2010) have set specific goals such as requiring EU member states to ensure all new buildings to be 'nearly zero energy' by the end of 2020.

Despite these declared goals, a standard definition of 'zero energy' or 'nearly zero energy' building does not exist. As discussed by Hernandez and Kenny (2010) definitions are multiple and varied, but always focus on the energy use of the buildings in operation, without considering energy use in other parts of the life cycle, such as manufacturing, construction, maintenance, disposal, etc. This life cycle aspect is however increasingly important as buildings use larger quantities of materials and systems to achieve 'zero energy' in operation, and therefore should be included within building energy assessment and rating methods. In this paper we propose a methodology for a life cycle building energy rating (LC-BER), based on accounting for embodied energy of buildings and on the integration of the embodied energy results with current assessment methods of energy use in operation. Is intended to be a simple method for an easy and prompt implementation within current BER methods, which could have immediate effect on the approaches taken to move towards buildings with very low and zero energy use in operation.

2. Current building energy assessment and rating methods

Building energy assessment and rating methods are becoming ever more important instruments in the implementation of

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building regulations and codes in many countries. Since 2006 the EPBD stipulates that energy certificates be issued to prospective building buyers or tenants throughout the European Union (EU). These energy certificates or building energy ratings (BERs) provide information about the potential energy performance of a building, which, as suggested by some studies (Eichholtz et al. 2009; Australian Government—Department of the Environment Water Heritage and the Arts, 2008; Nevin and Watson, 1998), can serve to influence the value of the property. Additional key information provided by BERs are recommendations about measures to improve the energy performance of the building, with the ultimate goal being to promote energy savings in the building stock.

The main characteristics of a BER system are robustness, transparency, reproducibility and sufficient accuracy (Arkesteijn and Dijk, 2010), for the results to be recognized and accepted by the full range of market stakeholders. However the system also needs to be cost-efficient, meaning that calculations need to be carried in a short time and at low cost so the implementation and potential impact of the BER system is not outweighed by its cost.

There are two main types of BERs:

1. Operational rating: A measured energy rating based on measurements of annual amounts of building energy use in operation. This type of building energy rating is used in countries such as the UK and Ireland as a 'display certificate', which has to be shown in a prominent place in public buildings, and is particularly useful to promote energy improvements through building operation and management, comparing the annual and actual real energy usage.
2. Asset rating: A calculated energy rating obtained from a calculation based on the building characteristics and applying standardised indoor conditions and occupancy. It is intended to provide prospective buyer or tenants an indication of expected energy performance of the building.

There are many methods and tools available to calculate building energy performance, from dynamic simulation tools such as EnergyPlus (US Department of Energy, 2010), which allow calculation of detailed energy end-use in sub-hourly intervals, to simplified methods such as described in EN ISO 13790 (CEN, 2008), which allows calculation of monthly values for energy use related to heating, cooling, lighting and hot water. Energy performance calculations can be used to compare and ensure compliance with building regulations and standards and to obtain a BER.

In contrast with this focus of BERs on the building energy use in operation, research carried out over the past few decades shows the importance of considering a life cycle approach on building energy performance analysis. A review by Sartori and Hestnes (2007) compiled information on 60 case studies of conventional and low energy buildings, indicating that embodied energy in conventional buildings, over their life cycle (generally considered as a 50 year-period), can vary between 2% and 38%. As regulations and standards aim to progressively reduce operational energy use of the building, it can be expected that the relative importance of the embodied energy will become greater. For low energy buildings the review of case studies presented a wide range of values where embodied energy accounted for 9–46% of the overall life cycle energy use. Obviously as the energy use in operation diminished, the embodied energy accounted for a larger percentage of life cycle energy use, being 100% for buildings with zero energy in operation. However for those buildings where the annual energy balance equals zero, significant differences can be found as they use different materials and systems with different associated embodied energy. For example, an inefficient building with large energy use in operation would need a large investment (both economic and of embodied energy) to provide enough renewable energy supply to become 'zero energy' in operation. From a life cycle perspective, energy conservation measures should be prioritized before the installation of renewable energies is considered, as they can represent energy savings with little associated embodied energy. Despite this issue being widely known by building professionals and in some cases demonstrated through economic indicators, current building energy assessment methods and rating systems focus on energy use in operation and ignore the issue.

However, there exist opportunities to integrate life cycle aspects in building energy assessment and rating methods. Tools and databases such as ECOINVENT(Swiss Centre for Life Cycle Inventories, 2010) or ATHENA (ATHENA Institute, 2010), among others, can provide detailed life cycle data on environmental impact and embodied energy for building products and systems. There are also established environmental ratings for products, such as FSC for wood products (Forest Stewardship Council, 2010) or Eco-Label (EUROPEAN Commission, 2010) for various product categories, which do integrate life cycle aspects. The development of environmental product declarations (EPDs) and international standards under development for environmental assessment of building products and systems (CEN TC 350, 2008; ISO TC 59, 2008) will also help towards standardization of environmental assessment of buildings and products.

It is necessary to integrate those efforts with the current building energy assessment and rating methods, which are well developed but miss the important life cycle aspect.

In this paper we propose a methodology for a life cycle building energy rating (LC-BER), based on accounting for embodied energy of buildings and on the integration of the embodied energy results with current assessment methods of energy use in operation. Is intended to be a simple method for an easy and prompt implementation within current BER methods, which could have immediate effect on the approaches taken to move towards buildings with very low and zero energy use in operation.

3. Proposed method for a life cycle building energy rating—LC-BER

Life cycle energy analysis of buildings has been researched for decades, from studies during the 1970s as by Hannon et al. (1978) to more recent studies as presented in reviews by Sartori and Hestnes (2007) or Ortiz et al. (2009). The importance of including life-cycle issues within building regulations has also been highlighted by Casals (2006) , Zabalza Bribian et al. (2009) or Zold and Szalay (2007). The current need for a new methodology to be developed has been highlighted by Hernandez and Kenny (2008a, b) who demonstrated with some very-low energy case study buildings that a reduction of energy use in operation does not always imply a reduction of life cycle energy use.

An extension of assessment methods and ratings into a life-cycle building energy rating (LC-BER) is proposed, by a simplified accounting method for embodied energy data of building components and systems, and presenting all in a common indicator in kWh of primary energy per square meter of building area per year—a currently used and widely understood measure. The process is illustrated in Fig. 1.

The current methods for BER have typically two main steps. Step 1 is building information gathering. Information needs to be collected about building type and size, envelope characteristics, heating, cooling, ventilation and hot water systems and controls, lighting, etc. The main source for this data is building plans and specifications for new buildings, complemented by surveying of