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Towards zero carbon design in offices: Integrating smart facades, ventilation, and surface heating and cooling

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ABSTRACT

This paper discusses an overall strategy for reducing energy demand in non-domestic buildings, mainly focusing on office developments. It considers four areas: reducing internal heat loads; addressing passive design through the building construction; using efficient and responsive HVAC systems and focusing on chilled (heated) surface systems; integrating renewable energy supply systems into the building design. The impact on energy use and carbon dioxide emissions will be discussed. The paper will draw from a range of design projects carried out in Europe, where this integrated approach has been applied, and then explore the benefits in relation to applications in the Middle East and China. Energy modeling results, to inform the design process will be presented, using energy simulation for three case study locations, in Zurich, the Chongqing and Abu Dhabi.

1. Introduction

Reducing energy demand in buildings requires an integrative and holistic approach to all aspects affecting energy performance, whilst ensuring comfortable healthy conditions for occupants, and within the context of the local climate. Achieving a low or zero carbon building is a combination of reducing energy demand and providing energy supply from renewable sources. In many cases it may not be feasible to provide a totally zero carbon building, and the concept of a low carbon building might be currently more appropriate to provide a bridge to eventually achieving zero carbon performance within acceptable costs. This paper discusses the process of arriving at a low energy, low to zero carbon building design, using an office building type as an example. The paper takes as a baseline, typical European design standards and techniques, based on buildings that the authors have worked on. It then applies the same standards to China (Chongqing) and UAE (Abu Dhabi) in order to explore how these standards would compare under different climatic conditions. The paper discusses how energy demand can be reduced, and then how low carbon performance can be achieved through the additional application of renewable energy. The paper discusses the need for energy storage, if the renewable supply is building integrated, although in many cases energy exchange with the grid is often used in practice to achieve a 'carbon neutral' building.

2. Low carbon design

A number of design models have been suggested to help achieve low energy and low carbon design. They generally focus on the elements of design as well as the design process. One example, using an integrated design process was developed through the International Energy Agency's Solar Heating and Cooling Programme Task 23 in 2003 [7] which was based on experience in Europe and North America. It consists of a series of design loops at stages of the design process, namely of, pre-design, concept design and design development. Performance targets aim to minimize heating and cooling loads, and maximize daylighting potential and the use of solar heat gains, together with efficient heating and cooling systems, and using renewable technologies to meet the energy demand loads. An iterative approach is used to produce a range of design alternatives, which are then tested through energy simulations. Another approach was developed by M-A. Knudstrup, Aalborg University, Denmark in 2004 [3], which requires a description of the environmental or sustainable building concept at the first stage of the building project. Subsequent stages are developed around an Analysis phase, to provide a statement of aims, a sketching phase, where thereof architecture and engineering are integrated into the design process, a synthesis phase, to produce the building's final form, and finally, a presentation phase, where the project is clearly described for the building owner. The

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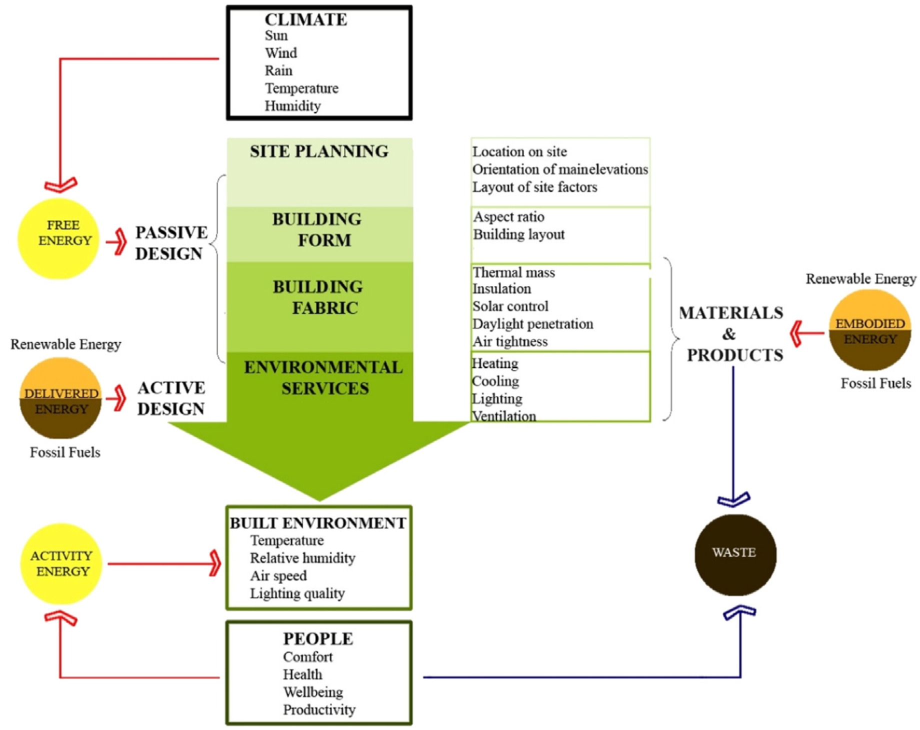

Fig. 1. The model of low/zero carbon design.

system developed by K. Steemers, Cambridge University, the UK, 2005, assesses the interrelationships and levels of integration of design parameters for low energy design in an urban context. It raises awareness of a range of environmental and design parameters rather than a rigid process, relating to the principles of low energy design. This is followed by steps for developing the pre-design context, the building design, and then the building services [3], with each phase broken down into aspects and sub categories. P. Jones, at Cardiff University developed an approach [6], beginning with climate data to help define the design objectives, then to passive design strategies, from site planning, building form to building fabric, followed by energy efficient building services, with renewable energy systems used to supply energy required by the building systems (Fig. 1). Also considered are waste associated with construction materials and products used, as well as waste generated in the process. Although there is no diagrammatic description of its links with process, the intention is that it is referred to at all stages, from concept through to detailed design.

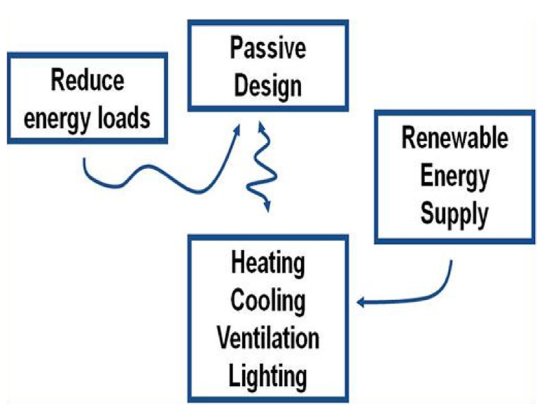

Fig. 2. An approach towards zero carbon buildings.

The above design systems can be simplified for low to zero carbon design to include four steps, reducing energy demand, passive design, mechanical systems, and the renewable energy supply (Fig. 2). In common with the above design systems, this simplified approach should be holistic, applied from the early concept stages of design, and tested through analysis simulation. The use of simulation should be to inform the design process, rather than dictate it, and therefore it should be carried out at early design stages. The four areas of the design process (Fig. 2) are used as a basis for discussion in the following sections, with specific reference to office design. The discussion draws from experience of providing building physics advice to many design projects in Switzerland (in collaboration with Kopitsis Bauphysik Ag). This is followed by an example of building simulation of a typical office development in three different climate locations.

2.1. *Reducing internal heat gains*

The first step in any low energy design should be to reduce the electrical energy loads in the space, from lighting, small power (plug loads) and any other incidental energy use. This will have the added benefit of reducing the cooling load demand needed to exhaust the heat gains from this equipment. In locations requiring heating, these incidental heat gains can prove useful in meeting the space heating demand. However, for most modern office designs there is little space-heating requirement, and so these heat gains

Table 1
Internal heat gains to space from ‘current’ good practice and ‘efficient’ design [1].

Internal heat gains	Current (W/m^2)	Efficient (W/m^2)
Internal gain from people (~12 m^2/person)	6.0 (sensible) 5.0 (latent)	6.0 (sensible) 5.0 (latent)
Plug load	10.9	4.9
Lighting	12.0	7.0 [12]
Total (sensible)	28.9	17.9