



Review

A review on sustainable construction management strategies for monitoring, diagnosing, and retrofitting the building's dynamic energy performance: Focused on the operation and maintenance phase



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HIGHLIGHTS

- This study reviews the state-of-the-art in “energy” as well as “building”.
- Building's dynamic energy performance should be managed in the built environments.
- This study summarizes recent progress in the building's dynamic energy performance.
- The major phases can be categorized into monitoring, diagnosing, and retrofitting.
- This study proposes the specific future development directions and challenges by phase.

ARTICLE INFO

Article history:

Received 21 April 2015

Received in revised form 1 June 2015

Accepted 17 June 2015

Keywords:

Sustainable construction management

Building energy performance

Dynamic approach

Urban organism

Built environment

ABSTRACT

According to a press release, the building sector accounts for about 40% of the global primary energy consumption. Energy savings can be achieved in the building sector by improving the building's dynamic energy performance in terms of sustainable construction management in the urban-based built environments (referred to as an “*Urban Organism*”). This study implements the concept of “*dynamic approach*” to reflect the unexpected changes in the climate and energy environments as well as in the energy policies and technologies. Research in this area is very significant for the future of the building, energy, and environmental industries around the world. However, there is a lack of studies from the perspective of the dynamic approach and the system integration, and thus, this study is designed to fill the research gap. This study highlights the state-of-the-art in the major phases for a building's dynamic energy performance (i.e., monitoring, diagnosing, and retrofitting phases), focusing on the operation and maintenance phase. This study covers a wide range of research works and provides various illustrative examples of the monitoring, diagnosing, and retrofitting of a building's dynamic energy performance. Finally, this study proposes the specific future developments and challenges by phase and suggests the future direction of system integration for the development of a carbon-integrated management system as a large complex system. It is expected that researchers and practitioners can understand and adopt the holistic approach in the monitoring, diagnosing, and retrofitting of a building's dynamic energy performance under the new paradigm of an “*Urban Organism*”.

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1. Introduction

1.1. Research background and motivation

According to the 2013 Survey of World Energy Resources published by World Energy Council, the global primary energy demand may increase by over 50% by 2050, and at least 80% of the increase is expected to be seen in the developing countries. Particularly, the total primary energy demand in China is projected to increase two-fold by 2035. Although the global energy resources can be shown to be sufficient at this point, some specialists forecast that the world's fossil fuel reserves would be depleted within 50 years in considering the increase rate of the global primary energy demand [1–3]. Meanwhile, regarding the global energy resources, global environmental issues such as global warming are considered very important, and the nuclear power plant disaster in Fukushima, Japan has raised the issue of radioactive pollution [4]. Thus, there is a need to use clean technologies to address such potential problems. Toward this end, significant capital investments should be made, and the global energy consumers should be ready to pay higher fees than they are currently paying for utility power.

The building sector accounts for about 40% of the global primary energy demand, and it is estimated that the potential energy savings that would be achieved in the building sector is between 20% and 40% [5–8]. Various institutions have been established worldwide to realize energy-efficient and low-emission buildings. One of the most representative institutions is Energy Performance of Building Directive (EPBD), established on December 16, 2002 in

the European Union. EPBD forces building purchasers and tenants to provide the energy performance certificate (EPC) in the building sale or rental process so as to strengthen the management of the total energy consumption in the building sector. Ultimately, EPBD aims to achieve the potential energy savings in the building sector [9,10]. Particularly, such policy aims to monitor and diagnose the energy performance in the operation and maintenance phase of the building sector.

To make such policy more effective, it is required to consider the building's energy performance under the new paradigm of an "Urban Organism" [11]. In this paradigm, the building's energy performance can be relatively recognized and evaluated by the following various factors in the urban-based built environments; and therefore, it should be managed in terms of the "dynamic approach".

- The increase in the global warming potential as one of the environmental impacts has an effect on the increase in the heating and cooling demands of the existing buildings, which can change the energy consumption patterns of residents.
- Due to the decrease in the world's fossil fuel reserves for the energy supply, the energy price continues to increase; and thus, it can have an effect on the energy consumption patterns of residents.
- The energy consumption patterns of residents can be affected by various energy policies such as the carbon emissions reduction target (which has been implemented around the world to reduce greenhouse gas (GHG) emissions), the emissions trading

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