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Advancements in Building energy performance assessment: A Review

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Abstract:

Building energy performance assessment is crucial to ascertain the efficiency of energy use and is the basis to make any decision for enhancing energy efficiency. It can provide building owners and/or tenants with understandable information regarding how much energy being consumed and how the performance being appraised comparing with benchmarks, which consequently should be a motivation for the building owners to improve the energy performance when the performance is deficient and certain cost-effective energy saving opportunities be identified. This paper reviews the researches carried out in the field of energy efficiency assessment for buildings. It involved a combination of literature reviews, multiple case study research and comparative studies.

Introduction:

Sustainable development is a holistic, all-encompassing approach. There is increased focus towards integrating sustainable development concepts into design and operation of built environment due to major environmental issues such as air pollution, irregular rainfall, and rapid depletion of groundwater resources, rising sea levels, irreversible damage caused to freshwater resources, loss of biodiversity and degradation of quality of life. Rapid growth in the building construction sector to meet the increased needs of the society and extensive urbanization resulted in large scale exploitation of natural resources. Hence, sustainable development has become a common agenda to mitigate major environmental issues. Several initiatives were undertaken to conserve the eco-system.

Early attempts to conserve materials and energy in buildings required a holistic approach to address many aspects of sustainable development. As a result, it became necessary to redefine sustainable building to cover more features related to design, construction, operation, maintenance, and end-of-life. It was in this context, the concept of ‘green building’ was developed. A green building is likely to address the sustainable development objectives more comprehensively by adopting innovative methods during its entire life cycle. This review paper contains the previous work in the field carried out by various researchers.

Literature Review:

The residential sector consumes about 50% of the electricity produced from fossil fuels in Saudi Arabia. The residential energy demand is increasing. Moreover, a simple building energy performance assessment framework is not available for hot arid developing countries. ***Mohammad Al Hashmi et al*** proposed an energy performance assessment framework for residential buildings in hot and arid regions, which focuses on three performance criteria: operational energy, GHG emissions, and cost. The framework has been applied to three types of residential buildings, i.e., detached, attached, and low-rise apartments, in five geographical regions of Saudi Arabia. Design Builder® was used to simulate the energy demand in buildings over a whole year. Four types of efficiency improvement interventions, including double-glazed windowpanes, triple-glazed windowpanes, LED lighting, and split air conditioners, were introduced in 12 combinations. Overall, 180 simulations were performed which are based on 12 intervention combinations, three building types, and five regions. Three performance criteria were evaluated for each simulation and then aggregated using a multi-criteria decision analysis method to identify the best intervention strategy for a given building type and a geographical region in Saudi Arabia. Each building type with interventions consumes higher energy in the western, central, and eastern regions and consumes a lesser amount of energy in the southern and northern regions. The proposed framework is helpful for long-term planning of the residential sector.

In Ghana, the inability to solve peak demand constraints by finding a balance between reducing demand and increasing supply has resulted in power rationing coupled with erratic electricity supply. Various studies have reported the enormous influence energy assessment tools, contribute to solving building energy demand. However, no building energy standards are in place in Ghana and this is aggravated by lack of data for building energy consumption. As a first step towards developing a building energy efficiency assessment tool ***Addy Michael Nii et al*** aims to identify applicable energy efficient building assessment categories and criteria for the Ghanaian Built environment. As building assessment methods involve multi-dimensional criteria, a consensus-based approach is used to conduct the research. Hence, the Delphi technique is selected and conducted in two successive consultation rounds involving professionals and highly informed local experts from academia, government and industry in the domain of building energy assessment methods. The results reveal that international assessment methods are not fully applicable to the Ghana built environment, as reflected in the identification of new energy efficient building assessment criteria. The research is focused in Ghana and similar developing countries grappling with building energy problems. It is expected that findings from the study will provide further directions towards the full development of building energy assessment tool in such regions.

Existing buildings are likely to consume more energy and emit more greenhouse gases than new buildings because of inevitable deteriorations in physical performance. Accordingly, retrofitting of existing buildings is considered essential to reduce energy consumption and greenhouse gas emissions from the building sector. However, assessing the energy performance of existing buildings accurately has limitations because building materials undergo physical deterioration and the actual operational conditions differ from as-built documentation. There is also a difference in the level of data acquisition required for building energy performance assessment depending on the conditions of the building. ***Kyung Hwa Cho and Sun Sook Kim***, present types of methods for energy performance assessment of existing buildings considering this data acquisition level. We analysed various assessment methods, which were classified into three prototypes of methods according to the required level of data acquisition. Type 1 assessed the target building based on literature sources. Type 2 conducted on-site audit and assessed the target building based on additional collected data. Type 3 assessed the target building by further estimating the building properties through analysis of the measured energy data. The applicability of the proposed methods was demonstrated using case studies of three buildings located in Seoul, South Korea.

Subbarao Yarramsetty et al targets to provide a simplified energy analysis to assess the influence of the orientation of the buildings. The energy savings mostly depends on the solar heat gain and more often local factors including social lifestyle. A multi-storied, multifamily residential house in Afghanistan is considered as case study. The first step in this analysis is to develop a 3D model of the building. The second step is to study the energy scenarios for different orientations through simulations. Then the energy analysis is performed. In this study taking the whole building as a unit for energy analysis, 24 test scenarios are considered by changing the building orientation 15° rotation each time including the actual orientation. It is observed from the analysis of data collected that a saving of $1393 from the best orientation (+315° clockwise) to the worst orientation (+165° clockwise). The simulated electricity demand is validated by taking the original bills of the actual orientation and it is observed the values are 2.65% greater than the simulated values.

Different sustainability standards were applied to implement the concept of sustainable development around the world. Since the residential and services sector is highly dependent on the buildings and as one of the main parts of energy demand, they are the most important factors of the development of life-quality and environmental issues. With the importance of the buildings being mentioned; sustainability standards are significant issues to be executed on the buildings to reach the mentioned goals in those sectors, and since there are various types of these standards, evaluation is essential to choose which is more reliable and efficient to reach the sustainability-based goals ***Nima Norouzi and Mona Soori*** investigate different building assessment standards. The evaluating methods and scoring mechanisms are based on the Nexus category as one of the primary assessment measures. Finally, the methods of building sustainability assessment have been compared in these Criteria dimensions: ecological, social, and economical.

As renewable portfolio standards enforce the expansion of renewables on the U.S. grid in the coming years, old storage technologies must be re-evaluated for a dynamic, interactive future grid. Ice thermal storage, traditionally for diurnal load shifting on large central chiller plants, is also viable in packaged devices for most buildings that lack central plants. However, modelling of these unitary thermal storage systems (UTSS) has been very limited to-date. To help make packaged thermal storage modelling more accessible, this paper presents a recently developed OpenStudio measure for rapid analysis of UTSS. Using this measure, ***Karl Heine*** et al assess the UTSS implementation in new and retrofit retail buildings with both packaged single zone air conditioners (PSZAC) and packaged variable air volume (PVAV) systems. Each implementation is evaluated on annual energy use, fan energy use, load shifting efficiency, daily unused ice availability, and potential cost savings under various time-of-use rates. Deficiencies with schedule-based control are highlighted by comparing the daily unused ice and the cooling-electricity load duration curve. Annual energy use increases by 1.2–3.7%, but on-peak electric demand is reduced by 32.2–36.6%.

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Green building rating schemes are used in industry practice as a practical tool for sustainable development. Green building ratings facilitate conservation of natural resources and reduction in environmental impacts while satisfying the user requirements. The credit structure, indicators, level of certification, priorities allocated to environmental, economic, and social aspects of sustainable development vary widely among the green building schemes used in different countries. ***C.R. Subhash Varma, Sivakumar Palaniappan*** presents a comprehensive comparison of credit structure and indicators of ten green building rating schemes that are widely used in North America, Europe, and Asia. Green building schemes namely Green Globes, LEED USA, BREEAM, DGNB system, GRIHA, IGBC system, BEAM Plus, Green Mark, CASBEE and Green Star are considered. The comparison is performed at six different levels. The extent to which the sustainable development objectives are met in these schemes is evaluated. Further, this study examines the credit structuring of the two Indian green building schemes – GRIHA and the IGBC system, identifies the areas of improvement and proposes a framework for the next-generation green building scheme that could be adopted in India. The findings of this study are beneficial to improve the effectiveness of green building rating schemes in India.

Existing buildings are likely to consume more energy and emit more greenhouse gases than new buildings because of inevitable deteriorations in physical performance. Accordingly, retrofitting of existing buildings is considered essential to reduce energy consumption and greenhouse gas emissions from the building sector. However, assessing the energy performance of existing buildings accurately has limitations because building materials undergo physical deterioration and the actual operational conditions differ from as-built documentation. There is also a difference in the level of data acquisition required for building energy performance assessment depending on the conditions of the building. The aim of this paper is to present types of methods for energy performance assessment of existing buildings considering this data acquisition level. ***Kyung Hwa Cho and Sun Sook Kim*** analysed various assessment methods, which were classified into three prototypes of methods according to the required level of data acquisition. Type 1 assessed the target building based on literature sources. Type 2 conducted on-site audit and assessed the target building based on additional collected data. Type 3 assessed the target building by further estimating the building properties through analysis of the measured energy data. The applicability of the proposed methods was demonstrated using case studies of three buildings located in Seoul, South Korea.

Conclusion

This review has demonstrated the significance of building energy and environmental evaluations. Its responsibilities include evaluating the effects of environmental design principles as well as variables contributing to office building electricity use disparity reductions, such as photovoltaic gain alleviation orientations, energy-efficient strategies for built forms, ventilation, lighting, and services, and reductions in operating time and availability. New efforts will also include: numerous case study studies backed by energy performance use audit reports, findings, survey questionnaires, discussions, performance analysis and comparative studies; building energy simulation supported by performance test and correlative studies; and peer review process and group discussion meetings.

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