Technologies for Green Buildings: A Review of Energy Efficiency Perspective

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Abstract – The energy crisis is one of the prominent current issues drawn all over the world. The construction and occupational phases of buildings are one of major contributors to this problem. Modern buildings are created with advanced technologies to optimize the energy consumption of buildings while managing the occupants' requirements sufficiently. To this end, the green building concept is becoming increasingly popular worldwide. In green building construction, green technologies play a significant role when achieving building energy efficiency, hence have drawn the attention of recent researchers to investigate the energy-efficient technologies applicable to green buildings. However, it seems to be the application of these technologies is limited due to the poor public and investors awareness regarding these technologies. Therefore, this study aims to review the energy-efficient technologies that have been implemented in green buildings to achieve sustainability, through a desk study. The review focused on two types of green technologies: (1) implemented in new construction and (2) implemented in existing buildings. However, it seems to there is no significant difference in energy-efficient technologies in terms of new and retrofit. Review results further show that energy-efficient technologies can be classified into two categories: energy conservation techniques and energy generation techniques. Under the energy conservation twenty, (20) techniques were identified under five main elements: Heating, Ventilating, Air Conditioning (HVAC), lighting, window, roof, and walls. Soar lighting and solar wind hybrid system are the two main identified energy generation techniques identified through the review. It is expected that the findings of this study would enrich industry practitioners with knowledge of green technologies and thereby facilitate the selection of the most suitable technology to improve energy efficiency in buildings.

Keywords: Energy efficiency; Green building; Technologies.

I. INTRODUCTION

Sustainable development can be identified as the development which meets the needs of the present by compromising the ability of future generations to meet their own needs [1]. Green building is a major aspect that comes under the promotion of sustainability [2]. A green building can be defined as a design, construction, and operation which directly minimizes negative impacts and produce positive impacts on climate and the natural environment [3]. The global sustainability goals have led to the development of this green building movement within the construction industry [4]. The popularity and the acceptance gained by the green building practice have in turn resulted in the development of a variety of green technologies for enhancing sustainability performance during the construction process [2]. Adopting green technologies provides a wide variety of economic, social, and environmental benefits along with the growing awareness of climatic changes [5]. Green technologies implemented in green buildings can be classified under five main green features that are specified in green certification systems: sustainable site, water efficiency, energy and atmosphere, indoor environmental quality, and material resources. Among those green features "energy and atmosphere" feature become the most prominent because it took the highest portion in green certification (i.e., 35 out of 110 in LEED certification and 21 out of 113 GREENSL certification). One reason could be the current energy crisis in the world. These energy and atmosphere-related green technologies would encourage building owners and designers to complete a proper, systematic look at the building and site's energy flows to lower energy bills, assess the potential for renewable energy use, and improve environmental health impacts. For example, the application of high-energy efficient windows and green wall technology in a housing development can help to save 14-20% and 33-60% of operational energy [4]. In addition to that, a survey of 99 green buildings showed that they use 30% less energy than conventional buildings [3]. Even the developers tend to adopt green technologies such as solar technology and optimization of the thermal performance of building envelope, as it increases the market opportunities [6]. The forgoing literature confirms that green technologies would help to enhance the energy efficiency in green buildings. Further, existing literature evidence that several technologies could be used for green buildings in terms of energy efficiency. However, it seems to be there is less application of those technologies. One reason could be the lack of awareness among the investors as well as the public on those technologies. Hence, reviewing the available literature regarding the green technologies that can be applied for green building construction from an energy-saving perspective will help to address the energy crisis issues while increasing the performance of green buildings toward more sustainability

II. MATERIALS AND METHODS

To fulfill the research aim, a thorough literature review was conducted through the desk study. As a result, the available literature on green technologies has been gathered from journal articles, electronic sources, papers from the conference proceedings, and books.

III. RESULTS AND DISCUSSION

As suggested previously, the adoption of green technologies in buildings would enhance their sustainable performance, particularly in existing and new buildings. Two main ways can be applied green technologies for green buildings; new technologies and retrofit technologies. The technologies that can

be used to improve the green building performance in the initial phases of construction are new whereas technologies that are used for any refurbishment of an existing building aiming the increase green building performance are retrofit technologies. As per the review results, in terms of energy and atmosphere green feature, there seem no differences in technologies applicable to new construction and retrofit buildings. It was identified that available green technologies can be discussed under two main categories as energy conservation techniques and energy generation techniques. Energy conservation techniques referred to the decision and practice of using less energy whereas energy generation techniques discussed the sources. Table 1 shows the technologies that can be used for green buildings to enhance energy efficiency under each category.

Table 1: Technologies used in green buildings toward energy efficiency

Criteria	Technology
Energy Conservation Techniques	**HVAC** • Optimum Start/Stop Controller • Variable Frequency Drives (VFD) for Motors • Free Cooling Applications • Energy Recovery Ventilator (ERV) • Demand Control Ventilation (DCV) **Lighting** • Light Emitting Diode (LED) Lighting • Occupancy-Based Lighting Control System • Daylight Linked Lighting Management System • Lighting Controlled by Time Scheduling **Window** • Low Emissivity Application • Multi Pane Glazing • Vacuum Tube Window • Window Frame **Roof** • Roof insulation • Green roof application • High-albedo roof paintings • Transparent roof / Sustainable daylighting **Wall** • Wall insulation • Solar Shading Elements • Green Wall
Generation Techniques	• Solar Lighting • Solar-Wind Hybrid System

Source [1-6]

As observed in Table 1, approximately twenty (20) energy conservation techniques were identified under five main elements: Heating, Ventilating, Air Conditioning (HVAC), lighting, window, roof, and walls.

The HVAC system is the largest energy consumer out of the systems in a building. Hence, considerable energy savings may be achieved through energy efficiency measures. Building HVAC systems are designed for high-load conditions that are only experienced for short durations. Therefore, the installation of variables and controllers will maintain the required speed of the fan, and pump for the load requirements (i.e., Optimum Start/Stop Controller, VFD, and DCV). Free cooling application is another technology that would reduce energy consumption using Phase Change Materials (PCM) which store the abundant atmospheric night cool energy and use that energy during daytime to keep room comfort conditions within the desired level. ERV improves an HVAC system's energy efficiency by preconditioning outdoor ventilation air with the aid of indoor exhaust air. Along with the HVAC system, the lighting system is comparatively one of the biggest energy consumers within buildings. Through the appropriate selection of light sources, energy-efficient equipment usage, and effective controls, vast amounts of energy can be saved. When considering the power consumption, Luminous flux, efficiency, and energy cost LED lights to show more performance (More than 75%) than incandescent and fluorescent lights. Occupancy-based control systems, daylight-linked control systems, and time-scheduled control systems belong to the automatic lighting control systems where turning lights on and off to precisely control bulb illumination based on a particular purpose. Windows provide residents with light, a view, and fresh air, they are the most essential factor in a building's energy use. Window's overall heat transfer coefficient (or U-value) is generally five times that of other building envelope components (e.g., walls, doors, etc.) and around 20-40 percent of energy in a building is wasted through windows. Roofs and walls considerably engage in heating and cooling in buildings and utilized appropriate technologies effectively in minimizing cooling and heating demand in buildings. Soar lighting and solar wind hybrid system are the two main identified energy generation techniques. Solar and wind are two renewable energy sources that are vast, long-lasting, and pollution-free. Photovoltaic (PV) technology is one of the main outcomes of electricity generation through solar radiation. Durable, simple designs, require little maintenance, and convert solar radiation directly into electrical energy features increase the willingness towards those techniques. Solar wind hybrid systems utilized the advantage of high solar radiation and less wind speed at daytime and less solar radiation and high wind speed at nighttime.

IV. Conclusion

Many recent studies reported the significance and necessity of energy-efficient building designs to reduce the energy crisis and other negative effects of high energy consumption. This improvement can be fulfilled with the selection of suitable green technologies for buildings as stated in Table1. However, Table 1 is limited to the identification of technologies that would help to minimize energy usage, and it is recommended that further exploration of the significance of those techniques towards each sustainable pillar helps to increase sustainability performance.

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