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An Exploration of Green Engineering in Building Design

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Abstract

Malaysia is embracing green construction practices to promote sustainability in the built environment. This research aims to make existing residential structures more sustainable by examining green engineering-based technologies available and their preferences. A survey was conducted in Johor Bahru, involving 384 responses after a thorough literature analysis. The study analyzed various green engineering-based technologies, including solar energy, wastewater treatment, rainwater harvesting, window shading, natural ventilation, smart PDLC film glasses, roof thermal insulation, and smart home control panels. The results showed that solar panels and daylighting systems were the most preferred, with a mean index score of 102. People favor green engineering-based technologies due to their familiarity and low cost. Future research should consider the chosen green technology and sustainability knowledge of people, with participation from people throughout Malaysia potentially expanding the scope of this research.

Keywords: Green, Engineering, Building, Design and sustainable

INTRODUCTION

As a result of the negative impacts of infrastructure development and the use of non-renewable energy sources, Green Engineering has become more important in the current framework. A method of design known as "green engineering" prioritizes the well-being of both humans and the planet via the application of engineering concepts, scientific knowledge, and technological advancements. Sustainable and green real estate revolve on designing buildings that are both environmentally friendly and energy efficient. Methods that maximize the utilization of processes and products, use systems analysis to reduce harmful hazards to Mother Earth, and include environmental impact assessment techniques are the focus of this research article.

Sustainable and energy-efficient building design makes use of a variety of design ideas and technology. First, let's take a look at what influences a building's sustainability. The construction materials must not harm the environment in any way. To avoid depleting any "specific" resource for infrastructure development, we may utilize recycled material for this purpose, which can be sourced locally to cut down on shipping costs and carbon dioxide emissions. There should be some limitations on the content, however. It has to be safe to handle, resistant to corrosion, and able to keep heat and electricity from escaping. On top of that, green design is primarily concerned with preventing energy loss. Various parts of the construction need specialized materials. In soundproofing, for instance, high-quality insulating materials used in walls, floors, and ceilings lessen the propagation of noise from one room to another.

Considering materials that are especially engineered to absorb or block sound waves, such glass wool and polyester, which are used for acoustic insulation. Extra soundproofing may be achieved by installing windows with two or three panes of glass. The air space between the panes of glass reduces the amount of noise that may be transmitted. It is also advised to include acoustic panels, rugs, and curtains into interior spaces to absorb sound and prevent reverberation, whether in an office or a family. A great deal of planning goes into the design phase as well. It is important to strategically organize room layouts such that shared spaces reduce the direct transmission of sound. Location of items and activities that generate noise needs careful thought.

Furthermore, we will examine the two most significant forms of energy loss in any given system: light and heat. Avoiding power loss is as simple as keeping an eye out for actual cracks in wire. Next, adopting energy-efficient lighting technology like LED bulbs is a good idea. These bulbs not only use less power but also last longer, so you won't have to replace them as often. Choose energy-efficient and thermally-resistant construction materials. Low U-value windows and thermal mass materials are examples of what fall under this category. One way to determine the thermal conductivity of a material is by looking at its U-value, which stands for thermal transmittance. Lower heat loss may be achieved by installing low-U-value energy-efficient windows and maybe even by contemplating double or triple glazing. To avoid energy waste and drafts, use doors with good seals. Reduce the quantity of sunshine that enters a structure by installing shade devices like blinds or overhangs.

During warmer weather, this helps lessen the need for cooling. Also, make use of energy recovery ventilation systems to recirculate hot air from the exhaust into the new air coming in. The amount of energy required for conditioning is reduced when incoming air is pre-heated or pre-cooled. Heating, ventilation, and air conditioning (HVAC) systems are the most polluting and energy-wasting components of every facility. Heating, Ventilation, and Air Conditioning, or HVAC, refers to the integration of many technologies that regulate the air quality (including temperature, humidity, and air purification) inside a building. Achieving a comfortable temperature and satisfactory indoor air quality is its primary objective. Reduced reliance on fossil fuels is one way in which its industrialization into renewable energy systems may boost the efficiency of green buildings. It takes energy from the sun and stores it in solar panels, which are subsequently used to power the HVAC systems in your building. For the best results, regular maintenance is also required.

Table 1 Cost of Green Building in India

Cost of Green Building in India	
Renewable energy:	Costs can vary between Rs. (Indian rupees) 150 - 250 thousand per KW capacity.
Additional design time:	This can vary, but the design time might be significantly greater if the project team chooses building simulation to achieve building efficiency.
Building envelope:	The building envelope includes materials such as high-performance glazing and windows, insulation, green roofs and shading devices.

Building materials:	Incorporating environmentally conscious materials can sometimes be tedious and costly. The project team should try to use the most efficient lighting, low flow bathroom fixtures and other materials that are salvaged, recycled or rapidly renewable.
Green building certification:	Many green buildings are certified. Most green building rating systems and certifications require a fee and an additional consultant.
Water management:	A truly green building will have a rainwater harvesting system. Most green building projects also include a decentralized wastewater treatment system.
High performance HVAC and controls:	An air conditioning system with a high coefficient of performance (COP) will cost more upfront, but the payback is usually fast enough to easily justify purchasing the system. While there are low-cost technologies available for this, very few people seem to be aware of their existence.
Worker training:	Workers will need training so that they minimize damage to the site during construction. They will also need to be informed about construction waste management practices and other pollution control measures.
Operation and maintenance :	The building owner will need to ensure that the building continues to be green after it is commissioned. This requires practices such as waste management, building performance measurement and reporting, eco-friendly cleaning practices and landscape maintenance.

LITERATURE REVIEW

Zhao, Jiaming. (2024). As a result of the exponential growth in human prosperity brought about by innovations in science and technology, people have come to appreciate the critical role that nature plays in ensuring their own existence. Architecture, being the most significant space for human activity, has become an essential component in the context of the globe progressively promoting carbon neutrality. Conventional structures have failed to provide the necessities for a high-quality existence due to their high levels of pollution, energy consumption, and expense. Concurrently, there has been a rise in the importance that people place on a building's aesthetics and comfort. Designing and constructing green buildings has grown in importance as a crucial tool for preserving ecosystems and protecting the natural world. Using a literature study as its foundation, this article examines green building materials, describes their benefits and application breadth, and compares and contrasts the present state of conventional and green building development trends. In order to serve as a resource for those involved in green construction practices.

Zheng, Leilei. (2021). We should highlight green building since it has a significant influence on building design. Green building design principles, when applied to home plans, may provide much superior results. However, in order to be of greater service to the construction industry, green building design concepts must adhere to certain guidelines. This study provides a concise analysis of the green building concept's application in home design based on the linked principles in its development and the combination of theory and practice. For the development of the building sector, it offers a few points of reference.

Wang, Qing. (2024). Although people's level of living rises with societal growth and advancement, environmental issues such as pollution and resource constraints also arise. Sustainable development has risen to the forefront of the Chinese government's agenda, with construction engineering ranking among the country's most energy-intensive sectors. Thus, green construction has grown into a popular architectural idea, and the state has proposed greening and sustainable development. This paper's goals are to (1) examine and analyze green building design application situations and(2) provide a more in-depth explanation of green building design concepts and design points. Examine the interplay and consequences of green building design on occupants and the surrounding environment by dissecting the results of various green building design case studies, paying special attention to those pertaining to site selection, landscaping, lighting, HVAC, energy efficiency, and recycling. Put simply, it is critical to use green building design principles and create successful designs that positively affect people. Stakeholders in green building design, including architects, legislators, and associated stakeholders, may benefit practically from the research's recommendations for making green buildings more environmentally friendly and sustainable. The study also includes some reference values and is important.

Yu, Yonghui. (2024). In keeping with China's long-term strategy for sustainable growth, prefabricated home designs fully embrace the idea of green construction. But we still have a way to go in terms of green building optimization, prefab residential building design quality, and energy and resource efficiency. There are still a number of obstacles that must be overcome throughout the construction process when using prefabricated residential building designs as opposed to more conventional approaches. Design issues, processing and material selection problems, and the high needs of construction coordination are all examples of these obstacles. In order to promote the sustainable development of the construction industry and enhance the application of green building concepts in prefabricated residential design, this paper discusses practical measures for implementing green building design in prefab residential projects.

Liang, Shuang et.al. (2024). With the deepening of the concept of green building design, the course of university education gradually exposed many problems in the teaching of architectural design theory; based on the existing mode of teaching and combined with the needs of architectural design practice it proposed the “integrated” method of green building design. It is an effective way to improve the overall level of green building design.

GREEN BUILDING DESIGN PRINCIPLES

Green energy conservation is based on the following principles: to encourage the most effective transformation and use of energy inside the structure; to maximize energy consumption; Reduce carbon emissions over the building's full lifespan; An effort to minimize energy use without sacrificing comfort; Achieving the aforementioned goals while keeping building maintenance expenses to a minimum is the goal.

Green Building Features

Regional, externality, economic, and other life-cycle viewpoints, as well as five facets of indexing impact orientation, are the primary features of environmentally friendly structures. Features exclusive to a certain area. The terms "regional characteristics" and "building conditions" are used interchangeably; each location has its own unique set of circumstances that dictate how a structure should be designed and used. Taking into account factors such as local climate, natural resources, economic level, customs, and more, architects must develop technological techniques for environmentally friendly, low-carbon structures. To illustrate the point, southern buildings, in contrast to their northern counterparts, should prioritize the regulation of refrigeration and air conditioning systems. Features seen from the outside. Taking the structure and its surroundings into account as a whole is necessary when dealing with exterior features. For instance, while developing and constructing buildings, businesses should think about the environmental advantages that come with green and low-carbon structures. The ongoing improvement of technology is accomplished with the help and support of national policy. Nevertheless, given the current state of affairs, developers do not seem very enthusiastic about creating green and low-carbon buildings. To change this, the government should establish active policies and guidelines that demand low-carbon development and lower developers' development costs through regulation and control. Instead of chasing after a green but expensive technology stack, the construction industry should focus on controlling and reducing carbon emissions, which means that the cost of technologies and measures used in building projects should be considered. The green low-carbon building follows an overall optimization design for its structure. With the help of cutting-edge technology and materials, it optimizes its use of land, energy, materials, and water to reduce environmental load, including carbon emissions, and ultimately achieves cost savings while maintaining balance. A comprehensive view of the life cycle. Sustainable and low-carbon practices should inform every aspect of a building's design and construction. To achieve a low-carbon, environmentally friendly building, it is important to start with a comprehensive picture of the building's life cycle during the design phase and carry over the green idea from that phase into the construction management phase. A direction of indexed effects.

Sustainable Development

Environmentally responsible construction begins with a focus on long-term sustainability. Integrating and carefully coordinating ecological environment design with urban building design is an essential part of the green building design process. An energy-efficient building is one that uses less energy overall without sacrificing comfort for its occupants, as opposed to non-efficient structures. This allows the building to maximize its energy efficiency. Unlike more conventional approaches to architecture, green building design prioritizes preserving natural resources, minimizing impact on the environment, and providing a comfortable atmosphere for occupants.

People-Oriented

Being "people-oriented" is the most fundamental design concept because people—the building's designers and users—become the project's primary focus. It is important to think about the potential negative effects on human health while choosing eco-friendly and green construction materials. Simultaneously, the design's secondary principle is to make sure the user's living space is clean and comfortable by utilizing better technology and technology, making the most of natural light and wind to make sure the indoor climate is better for group activities, and so on.

MATERIALS AND METHODS

The study's two components were a survey questionnaire and an extensive literature review.

Questionnaire survey

In order to find out which green engineering-based tools are most popular for making existing homes more eco-friendly, researchers sent out questionnaires. Residents of Johor Bahru were the ones that received the questionnaire. According to the sample size table by Krejcie and Morgan we have 384 valid feedbacks to work with. The questionnaire contained a picture and short description of each technology that relies on green engineering. This is to provide survey takers with a general notion of the green engineering-based technologies that will be useful in answering the questions. The first set of questions asked respondents to rank the technology on a 5-point Likert scale, while the second set of questions asked respondents to indicate the range of prices they would be prepared to pay for each item. The data produced using the mean index, as given in equation, is analyzed using IBM SPSS Statistics software.

$$Mean\ Index = \frac{\sum(1X_1+2X_2+3X_3+4X_4+5X_5)}{\sum(X_1+X_2+X_3+X_4+X_5)}$$

where;

X_1=Number of respondents on scale 1
X_2=Number of respondents on scale 2
X_3=Number of respondents on scale 3
X_4=Number of respondents on scale 4
X_5=Number of respondents on scale 5

RESULTS AND DISCUSSION

The results of the research, derived from an extensive literature review and analysis of the survey questionnaire, are presented in depth in this part.

In order to promote sustainable construction practices, it is necessary to investigate the current green engineering-based technologies.

We selected nine different kinds of green engineering-based technologies—solar energy, wastewater treatment, rainwater harvesting, window shading, housing landscape, natural ventilation, smart PDLC film glasses, roof thermal insulation, and smart home control panels—from the literature review. Table 2 shows that all of them contributed considerably to a building's sustainability in various ways.

Table 2. Contribution of green engineering-based technology towards sustainability. ***Users' preference of the green engineering-based technology***

Green engineering-based technology	Contribution towards sustainability
Solar panel	the most environmental-friendly to generate power Enhance ecofriendly value of building Produce more renewable energy Reduce consumption of raw materials by replacing roof with building integrated photovoltaics (BIPV) Promote production of solar energy which considered as finest renewable energy
Wastewater treatment	Conserve water consumption Reduce pollutants to be released into catchment areas Curb scarcity of water supply Reduce power consumption and substitute for fertilizers Microfiltration to treat laundry wastewater require less expenses and polluted water not generated
Rainwater harvesting	Decrease consumption of water Prevent water wastage Decrease non-renewable energy usage

Green engineering-based technology	Contribution towards sustainability
	Lessen utilization of clean water Conservation of water
Window shading	Reduce energy consumption of cooling load Enables conservation of energy from consumption of artificial lighting Decrease thermal loading decrease, therefore consequently requires less cooling load Minimize cooling loads consumption Provide optimum natural lighting, thus save energy usage on electricity
Housing landscape	Contribute to less gain of heat energy that requires high power consumption Reduce consumption of cooling energy Provide cooling effect to surrounding area consequently provide natural cooling Provide catchment areas for runoff and contribute to indoor comfort temperature with minimal power required Minimize heat gain, therefore requiring less air conditioning usage
Natural ventilation	Decrease usage of energy in building Provide comfort temperature, consequently reduce utilization of air conditioning and fans Improve air flow without using so much electricity for cooling Better efficiency of air flow and reduce power usage Reduce cooling loads
Smart PDLC	Decrease heat gain, then reduce usage of air conditioning Lower the usage of lighting Regulate thermal gain of building consequently lessen cooling loads Promote energy efficiency Enhance the performance of cooling loads with minimal power
Roof thermal insulation	Decrease thermal radiation Enhance thermal reflectance and requires less energy to cool the building Enhance efficiency of building energy Declining temperature in building for optimum usage of mechanical cooling Minimize heat gain and deduction of energy required in building
Smart home control panel	Saves energy consumption at home Reduce unnecessary wastage of electrical consumption Reduce the usage of artificial lighting Decrease the usage of energy Managing energy consumption with integrated automation system monitors power consumption of building

Solar power is well acknowledged for its practicality and environmental friendliness. As far as power generation goes, it's supposedly the greenest option. Solar panels may be installed on residential roofs to collect sunlight and convert it into electricity. As solar panels continue to be improved, the production of power will become more substantial, reducing reliance on fossil fuels. As a result, emissions of carbon and other greenhouse gases may be drastically reduced. It is possible to reduce the use of freshwater for wastewater treatment by recycling and treating wastewater. It is possible to recycle wastewater for use as a crop irrigation or even as a fertilizer. However, wastewater treatment has the potential to lessen the number of pollutants discharged into catchment regions, which in turn reduces the likelihood of water pollution. More than that, using rainwater collection systems may cut down on water use. Reducing pressure on freshwater supplies, daily water demand is met by collecting rainwater. Rainwater collecting has the potential to save water for essential uses, which is becoming more vital as the human population grows. Window shade is an important part of maintaining a comfortable interior climate by reducing the amount of sunlight that enters the structure. This is seen when the energy consumption of cooling loads is reduced after installing double glazing and solar film on the windows.

In addition, optimizing the louvers and blinds allows for the most natural light to enter throughout the day. Because of this, window shading is necessary to lessen the building's reliance on cooling loads and artificial lighting. A more effective shading system may be used in residential landscapes to regulate heat gain inside buildings. Appropriate trees may block the sun's rays from reaching a home's interior. Additionally, the region immediately around the structure has a cooling impact due to evapotranspiration, which is produced by plants. Better mechanical cooling performance in the building is a direct result of a well-designed residential landscape, which in turn leads to reduced energy usage. In addition, you may naturally cool your home using natural ventilation and very little artificial ventilation by following these steps. It is recommended to open the windows at night so cold air may circulate within the building. Therefore, to decrease the power consumption of cooling loads, it is recommended to include mechanical ventilation and natural ventilation individually or together.

The result was a structure that used less energy while it was in use. The next eco-friendly innovation is smart PDLC film glasses, which can control the building's thermal gain with very little electricity. Use of PDLC reduces thermal gain in a structure, according to studies. Buildings may improve thermal comfort while minimizing cooling load consumption by using smart PDLC film glasses. One way to lessen a building's thermal gain is to insulate the roof. When compared to low emissivity paint, aluminum insulation is more effective in reducing heat absorption. Indoor thermal comfort may be achieved with less cooling energy by lowering the thermal gain. One further piece of technology that might help you manage your house's electrical appliances is a smart home control panel. Above all else, this technology allows for energy monitoring. The building's inhabitants may then control the running electrical appliances and maximize energy efficiency. The belief is that buildings or households that have building automation systems installed might drastically reduce their power consumption.

Users' preference of the green engineering-based technology

Figure 1 shows the data of the consumers' selected green engineering-based technologies to be installed in their houses. The most popular green engineering-based technique for making existing dwellings more sustainable is represented by the greatest mean value, while the least popular is represented by the lowest mean value. Housing landscape had the greatest mean score of 4.40 and was placed #1 in the study. A daylighting system comes in at number two with an average score of 4.33. Perhaps due to their relative simplicity, both of these technologies enjoy a higher level of popularity than competing options. Plus, they won't break the bank either. Contrary to popular belief, solar panels—which are notoriously costly to implement—ranked third with a mean rating of 4.27. This may be because customers might potentially save money on their electricity bills.

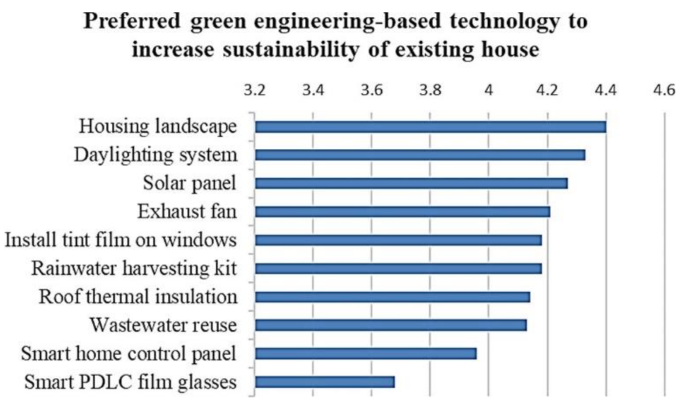

Figure 1. Mean for the preferred green engineering-based technology.

With a score of 3.68, smart PDLC film glasses are rated last. It is evident that the respondents had the lowest preference for retrofitting using this technology. Respondents may not have installed smart PDLC film glasses at their residences due to the high cost and unfamiliarity with the technology. On top of that, the majority of respondents live in terrace homes and think this technology is unnecessary because their residences aren't considered luxurious.

The willingness to invest on technologies based on green engineering is shown in Table 3. The table displays the pricing ranges for all of the items. The most popular price range for solar panels is "RM5,000-RM20,000," which accounts for 65.10 percent of the total. Due to the reasonable budget for solar panels, this is the preferred choice of most responders. Just 0.8% are prepared to pay the maximum amount. A large number of respondents are also prepared to pay, although within a more limited budget, for additional products including a smart home system, an exhaust fan, a rainwater harvesting kit, tint film, landscaping, and roofing insulation. Smart PDLC film glasses, on the other hand, had a very tight relationship between the proportion of respondents who were hesitant to pay and the percentage who were prepared to spend within a limited range: 43% and 40.1%, respectively. The exorbitant price tag of the technology could be to blame. In all likelihood, the vast majority of responders had never heard of smart glasses or its cutting-edge technology. Think about the daylighting system and wastewater treatment as two of the most affordable options; most people are prepared to pay what's needed. Maybe both might be considered acceptable costs.

Table 3. User's willingness to spend on green engineering-based technology.

Cost to spend on Green Engineering-Based Technology	Frequency Percentage (%)
Solar panel	
Not willing to spend	29.40
RM5000-RM20,000	65.10
RM20,000-RM40,000	4.70
>RM40,000	0.80
Wastewater treatment	
Not willing to spend	17.70
Spend as required	82.30
Rainwater harvesting kit	
Not willing to spend	24.00
RM1000-RM5000	70.80
RM5000-RM10,000	4.70
>RM10,000	0.50
Install tint film on windows	
Not willing to spend	15.60
RM100-RM300	47.90
RM300-RM500	24.20
>RM500	12.20
Daylighting system	
Not willing to spend	16.10
Spend as required	83.90
Housing landscape	
Not willing to spend	11.50
RM100-RM300	44.80
RM300-RM500	27.30
>RM500	16.40
Exhaust fan	
Not willing to spend	11.50
RM100-RM200	55.20
RM200-RM300	22.40

Cost to spend on Green Engineering-Based Technology	Frequency Percentage (%)
>RM300	10.90
Smart PDLC film glasses	
Not willing to spend	43.00
RM1000-RM3000	40.10
RM3000-RM5000	11.20
>RM5000	5.70
Roof thermal insulation	
Not willing to spend	26.80
RM1000-RM2000	53.40
RM2000-RM3000	19.80
Smart home control panel	
Not willing to spend	32.60
RM1000-RM2000	46.10
>RM2000	21.40

CONCLUSION

The focus of this research is on enhancing the sustainability of preexisting residential structures via the use of green engineering-based technologies. Solar power, wastewater treatment, rainwater collection, window coverings, landscaping, natural airflow, intelligent PDLC film, thermal insulation of roofs, and smart home control panels are all examples of green engineering-based technologies that have been acknowledged. Among 384 comments, the three most popular green engineering-based technologies are solar panels (4.27 out of 5), daylighting systems (4.33 out of 5), and housing landscape (4.40 out of 5). Respondents are inclined to pay the amount necessary for the daylighting system, according to the willingness-to-spend study. In the meantime, most people are simply prepared to invest a bare minimum on solar panels and landscaping for their homes. Thus, it is reasonable to infer that the primary factors contributing to the preference for green engineering-based technology in this research were its cheap cost and the fact that it was already acquainted to consumers. Researchers hope that construction industry professionals will utilize the study's results to upgrade older homes with green engineering technologies that increase energy efficiency and sustainability.

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