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# Zero-Energy Architecture: Practice of Digitalisation and Alternative Energy to Building Design

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**Abstract:** *Climate change is forcing the globe to undergo an energy transition, which has accelerated the shift away from fossil fuels and toward clean energy. In this paper, the researchers analyse and provide the past and current information regarding alternative energy in Malaysia, as well as the barriers renewable energy (RE) deployment for energy-efficient building (EEB). The data collected through reviewed of the literature by other authors (secondary sources) about RE, energy-efficient building, and digitalisation construction in Malaysia. The data reviewed could be used by the policy maker, assisting the local government, enlightening building industry players and the public to highlight the significance to practice and incorporating sustainable framework with the tapping of RE and digitalisation system for every planning that related to zero-energy architecture (ZEA).*

**Keywords:** Alternative Energy, Building Design, Digitalisation Construction, Green Architecture, Zero-Energy Architecture

## 1. Introduction

39% of the world's greenhouse gas emissions are from buildings. Cutting emissions in buildings will be important to reaching net zero emissions by 2050. Utilizing current, affordable technology, efficient, zero-carbon buildings improve local communities' health, equity, and economic development while lowering emissions [37].

The drive to Net Zero is currently the most prominent trend in building industry sector, and perhaps in all industries. To achieve this, data-driven construction methods and digitization are essential [36]. Energy conservation through energy efficient buildings has become increasingly important because of the global energy crisis. The three main factors that should be taken into consideration for energy savings in a building are building design, low-energy building materials used in building construction, and the use of RE technologies for various purposes. To ensure the world's long-term sustainability, renewable energy sources must be used to reduce carbon dioxide (CO2) emissions. Residential and commercial buildings in Malaysia use around 12% of the nation's total energy and 49% of its total power, according to CGS-CIMB Securities International Pte. Ltd. (CGS-CIMB).

Malaysia's government and private sectors have recently begun to implement green construction techniques, partly to benefit from lower energy costs, but also due to increased concern about the effects of the interior environment on wellbeing.

In order to maintain a safer environment for future generations, research for financial support must be sparked and a specific policy must be developed depending on the readiness of alternative RE resources and their local acceptance. It is also necessary to alter one's way of life, based on the concept of modern technology, which transcends materialism and society. To date, only a few substantial studies on Malaysians' attitudes on renewable energy use have been conducted. Implementing appropriate RE projects in the right contexts, while taking into account the political, policy, socioeconomic, cultural, and geographic circumstances of the nation, is crucial in Malaysia [2].

## 2. Data Analysis for Energy Crisis, Alternative Energy, Zero-Energy Architecture (ZEA), and Digitalisation Construction in Malaysia

The researchers analysed and summarized material from secondary sources from other authors to review all linked topics in Table 1. The topics reviews include energy crisis, alternative energy and barriers of alternative energy in Malaysia, energy-efficient building (EEB) and zero-energy architecture, digitalisation construction in Malaysia and government policies concerning alternative energy and digitalisation construction in Malaysia.

### 2.1 Zero-energy architecture (ZEA)

Green architecture promotes the preservation of nature in the planning, building, and maintenance of structures. In green architecture, the architect uses a design philosophy that takes the project's overall environmental impact into account. The efficiency and sustainability of energy resources, the protection of water and air resources, waste minimization, and the adaptation of materials to a changing climate are all factors that go into making a building or community "green" [35].

The term "net-zero buildings" originally referred to structures that produced enough energy for internal use. But experts concur that achieving net-zero carbon emissions for buildings is just as critical, if not more so, than achieving net-zero energy [33]. Net-zero buildings ultimately have a positive impact on both the economy and the environment. Apart from energy, net-zero carbon buildings also address waste, water, food, and other challenges; these are aspects we may also consider. For example, establishing urban farms near homes can cut down on the emissions caused by moving food while also fostering a sense of community among the locals. A net-zero structure has more aspects than that, and the context is crucial to its performance [33]. The first stage in designing a net-zero energy building is to adhere to design standards since it is crucial to identify the sources and inputs needed to quantify the outputs and determine what is required to balance the net-energy used. The second stage is to model energy use using a variety of tools and strategies to optimise the following building orientation, glazing area, exposure and shading, heat island reduction, lighting systems and capacities, temperatures, humidity, and relative humidity levels, landscaping, natural resources, and the overall system efficiency [32]. Figure 1 shows net zero village as an example of ZEA model that's has been discussed by the researchers.

**Figure 1: Net zero village (Image: Architecture for Humans)**

A building is considered to be net-zero site energy if, when measured on-site, it produces as much energy as it uses. In comparison to the energy content at the source, the net-zero source energy building is one that annually produces as much energy as it consumes. The building that uses energy efficiency and renewable energy solutions as part of the business model is known as a net-zero energy cost building. To emphasise, net-zero energy emission buildings are those whose designs consider the emissions generated by the structures' energy requirements. Various energy-efficiency measures are displayed in Figure 2. A more sustainable construction can lessen human effects on the environment. In Figure 3, this result is displayed [32].


**Figure 2: Various energy efficiency measures [32]**

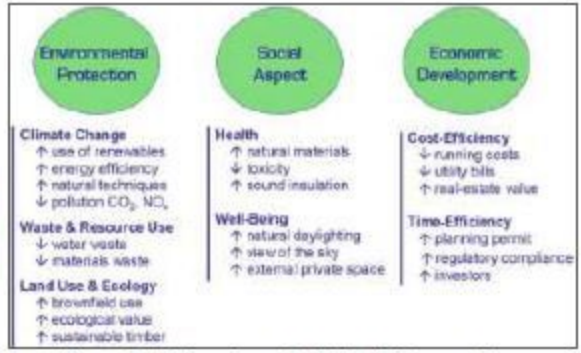


**Figure 3: Effect of sustainable buildings on the environment, social life, and economic development [32]**

The huge effects of climate change, fueled by rising energy and material use, are driving Asia Pacific's (APAC) demand for sustainable manufacturing and architecture, engineering, and construction (AEC). Key sustainability developments that have an influence on technology uptake and investment are:

a) Energy efficiency / reducing energy consumption
b) Green building initiatives
c) Resource efficiency / waste reduction
d) Green new deals / green infrastructure support

Increasing usage of RE APAC nations have started several programmes to improve sustainability and lessen environmental damage [34]. On the other hand, construction is one of the largest contributors to the combustion of fossil fuels, which is thought to account for about 80% of all man-made greenhouse gas emissions [38]. Figure 4 shows the influence of stakeholders across the building lifecycle (new construction and renovation).

**Figure 4: The influence of stakeholders across the building lifecycle (new construction and renovation). (Image: Cove.tool)**

## 2.2 Options for Alternative Energy in Malaysia

Table 1 shows data has been analysed by the researcher regarding energy crisis and alternative energy in Malaysia as to adapt zero-energy architecture (ZEA).

**Table 1: Review of alternative energy in Malaysia for energy-efficient building (EEB).**

| No | Energy crisis | Alternative energy in Malaysia | Barrier of alternative energy in Malaysia | Zero-energy architecture (ZEA) / Energy-efficient building (EEB) |
|---|---|---|---|---|
| 1 | Within the next 30 years, the world's reserves of oil and natural gas are expected to deplete [4]. | Water (hydroelectric and marine energy), solar (thermos and photovoltaic), wind (single turbine or wind field), geothermal sources, and biomass are examples of RE technologies [13]. | The use of RE in the energy sector faces several challenges, including higher costs and slower returns on investments, social opposition to the energy transition, sociopolitical acceptance issues, and the inability of the energy sector to produce and use RE from existing energy infrastructure. A few technologies, like small-scale solar energy systems and energy efficiency investments, require a high level of user participation, influence, and support. | A "green" building, based on the World Green Building Council, is one that has the potential to positive impact on the climate as well as the environment throughout its design, construction, or operation [31]. |

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| | | | The issues are cost and consumer expectations of quality. Wind and biomass technologies, for example, must maintain partnerships with existing residents whilst still making contributions to the social and economic structure [2]. | |
| 2 | In total, 98.7 million metric tonnes of energy will be consumed by 2030, which is roughly three times as much as in 2002. [27]. | Malaysia had simply ruled on a hydropower capacity of 100 megawatts; however, the Energy Commission might then consider adding it in the future. A microgrid is a regional energy grid that can operate on its own, according to the US Department of Energy. Thus, localised power generation and distribution are possible (usually through small-scale power systems using renewable energy sources like solar power). This lessens reliance on the national grid, which is beneficial in areas vulnerable to natural disasters or with inadequate infrastructure [7]. | The interviews revealed several key concerns, such as inadequate financial support, a due to the absence of awareness programmes, and subsidised electricity tariffs. This highlights the importance of governments raising public awareness, giving financial support, and developing compliance measures to manage solar companies in order to encourage solar development in Malaysia [12]. | Green buildings are built to recycle materials, by using less energy and resources, and release fewer pollutants. Green building criteria can be summarised as six factors: planning the site and managing the construction process, energy efficiency, the indoor environment, the use of materials, and waste and water management. Their requirements vary according to local factors. One of the criteria for green buildings is energy efficiency, which specifies consumption reduction and monitoring, renewable and alternative energy, and energy-efficient equipment and appliances [32]. |
| 3 | Malaysia's natural gas reservation, according to experts, will be finished in 70 years. It is also predicted that at current consumption rates, oil will run out in about 16 years [27]. | The two main categories of renewable natural resources used in Malaysia today are hydropower and solar energy. They contributed an average of 5-6% of the country's energy consumption over the past five years. Malaysia's renewable natural resources also include geothermal, biomass, and trash, and yet their cumulative impact is less than 1% [17]. | According to the findings of the study, the cost of renewable energy technology influences people's positions to use it [9]. | Reduced energy consumption, lower solar heat gain, capturing natural light, utilising renewable energy sources, as well as ensuring adequate testing and maintenance, must all be taken into account when designing an energy-efficient building [18]. |
| 4 | The intensity of energy consumption, energy wastes | Electricity Generation: 2020 **(Figure 5)** | As a result, industry players are less likely to | The Zero Energy Building (ZEB) programme is currently |

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| | (especially nuclear waste), side effects (like pollution), and fossil fuel availability (like geopolitical instability) all point to the urgent need to change the way energy is produced and used [13]. | Non-renewable: 147077 GWh (84%), Renewable: 28918 GWh (16%) Hydro & marine (25906 GWh: 15%), Bioenergy (2541 GWh:1%), Solar (471 GWh), Wind (0 GWh), Geothermal (0 GWh) [8]. | support biomass-related renewable energy production in Asian nations where carbon taxes and pricing have not yet been widely adopted. Second, there are the limitations of technological and technical experts, higher capital costs, financial assistance limitations, a lack of knowledge and awareness among the community, market developers' resistance and reluctance, in addition to the associated environmental challenges brought on by deforestation and greenhouse gas emissions as a result of manufacturing processes [21]. | supported by the European Union (EU), Japan, Singapore, and other countries committed to reducing energy use and carbon emissions (**Figure 6**), that also entails the design of extremely energy-efficient buildings merged with RE applications.<br>The majority of these nations aim to [25];<br>New public buildings in the year are ZEB categories by 2020; and<br>New public and private buildings (on average) are ZEB categories by 2030 [25]. |
| 5 | Due to its reliance on coal and natural gas, Malaysia is currently unwilling to transition away from conventional fuels anytime soon. Cost-cutting will be challenging even though current energy demands are overtaken by fossil fuels, and prices are climbing [7]. | Despite the current pandemic-related increase in the cost of producing solar PV systems, solar systems have actually shown a cost drop of 85% over the last ten years. From 2% in 1955 to nearly 20% today, efficiency has increased dramatically [15]. | The use of RE for power generation in some technologies in Malaysia has been slow, which is one of the industry's main challenges. The root causes have been examined along the following key dimensions relevant to the lifecycle of a RE project: (1) approval processes and land access, (2) financing, and (3) feedstock availability for power generation (particularly for biomass projects) [26] | The Diamond Building (**Figure 7**) has been constructed and designed using a sustainable building concept, reduced use of fossil fuels, water conservation, use of sustainable building materials, waste minimization and avoidance, indoor environmental quality, traffic and transportation management, and a construction and demolition management plan are some of the considerations [28]. |
| 6 | Malaysia's population and economy are both growing quickly, necessitating the search for alternative energy sources to meet the country's energy needs for both residential and commercial purposes. Renewable and alternative energy sources account for only 10% of Malaysia's total energy consumption [17]. | RE sources & energy value in RM million (annual) Forest residues (RM 11,984 million), palm oil biomass (RM 6,379 million), solar thermal (RM 3,023 million), mill residues (RM 836 million), hydro (RM 506 million), solar PV (RM 378 million), municipal waste (RM 190 million), rice husk (RM 77 million), and landfill gas (RM 4 million) [33]. | The identified gaps are mostly related to newer data, as well as technological and policy developments [35]. | Training to increase number of registered electrical engineer managements and promoting ISO 50001 (Energy Management) for buildings and industries (e.g Malaysia) [30]. |

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| 7 | Malaysia will be unable to meet the Nationally Determined Contributions ("NDCs") it ratified as part of the Paris Agreement if inaction or ineffective climate change action is taken. To significantly reduce emissions, Malaysia must safeguard carbon sinks and speed up the switch from fossil fuel-based energy generation to alternative energy sources like renewable energy [5]. | Up to 1,317.20 mm3/year of biogas and 2.1 104 kWh/year of electricity can be generated from animal dung in Malaysia. [1]. | | As a result, improving local environmental sustainability and reducing energy use depend heavily on the energy efficiency of buildings. Setting up a full ecosystem for delivering a green building and developing common green building objectives are important, there is currently no one official guide that all participants in the building and construction sector are required to follow but to check on three key initiatives; key initiative 1 (Green building designs), key initiative 2 (Sustainable construction practices), key initiative 3 (Green building materials) [22]. |

**Figure 5: Electricity generation.**

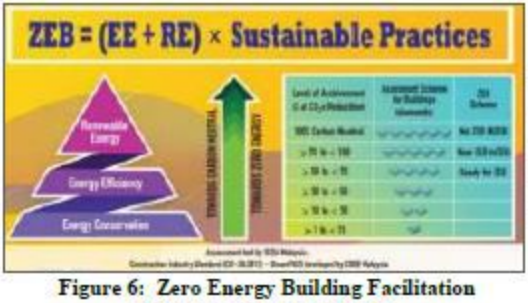


**Figure 6: Zero Energy Building Facilitation Programme (ZEB) (SEDA)**

**Figure 7: The Energy Commission Diamond Building (Suruhanjaya Tenaga)**

### 2.3 Digitalisation Construction

Due to their connection in APAC, the major economies, such as Malaysia, Singapore, and the Philippines, are becoming the ideal locations for high-value manufacturing. Net Zero will not be attained unless energy services are digitalized. Developing the essential digitalization of the energy system requires a governance solution, which may be achieved by doing the following:

a) Domestic Investment Strategic Fund (DISF) – Government to provide grants to accelerate the shift to high value-added, high technology, knowledge-intensive, and innovation based industries.
b) The Malaysian Government's Economic Recovery Plan (PENJANA), introduced in June 2020, announced the establishment of the National Technology and Innovation Sandbox (NTIS) to drive talent development.
c) The government is specifically focusing on digital transformation in the industries [34].

Today, it is essential that company procedures are transparent, and by embracing digitalization, this may be greatly enhanced. Information on behaviour, usage, failure models, performance indicators, emissions, and performance under stress is provided by digital technology. Such data analysis can then be formalised and used to create plans for both competition and sustainability [34].

The operation and maintenance of such buildings will heavily rely on artificial intelligence (AI), which will be used in smart metres, smart display boards that advise renters on how to cut energy use, lighting control vs shading, and air conditioning operation [32]. The most important advantages of digitalization in the sector include time savings in the delivery of building projects, increased productivity, faster work speeds, higher-quality documents, quicker reaction times, and easier working procedures.

### 2.4 Government Policy Concerning Alternative Energy

The following information is detailed in Table 2 on the researcher's review of a few government initiatives relating to alternative energy in Malaysia:

**Table 2: Government policy concerning alternative energy**

| Government policy | Institution/Organisation |
|---|---|
| Government buildings are required to comply with the National Building Energy Intensity (BEI) Labeling Program in order to improve their energy efficiency. It acts as a channel of information for others to learn about the energy usage of the structure. A benchmarking tool for evaluating the energy performance of buildings, the BEI is a ratio between the building's nett floor area (NFA) and the building's annual total energy consumption (kWh/year). Benefits of BEI labelling include determining how energy-efficient government buildings are and accelerating efforts to do so through Government Lead for example, to provide and disseminate information to occupants on the building's energy consumption performance in comparison to energy efficient buildings, to foster healthy competition among building owners in improving energy-use, and to assist the government in meeting its national commitment to reduce GHG emissions intensity of GDP by 45% by 2030 [7]. | Suruhanjaya Tenaga (Malaysia Energy Commission) |
| 30-year Government's ambition for Malaysia's Future Energy Landscape 2050. The eight essential interventions that have been identified to assist the government's 30-year goal are as follows; establishing a neutral organisation to coordinate all energy-related policies and coordinate the actions of key actors, the establishment of a comprehensive Malaysia Energy Policy outlining Malaysia's long-term energy strategy, the modification of Malaysia's Power Market to increase transparency in the power sector, liberalising the production and sale of electricity, establishing a research consortium for Malaysia's energy industry (the Malaysia Energy Research Consortium, or MERC) to promote innovation, foster cooperation among the various players in the energy ecosystem, and upskilling homegrown talent, consolidating and developing Malaysia's OGSE sector to help local businesses compete on both the domestic and international markets, streamlining and raising awareness of Malaysia's Intellectual Property (IP) system and processes, starting a required carbon accounting process, and introducing hands-on learning about environmental and energy awareness [7]. | Suruhanjaya Tenaga (Malaysia Energy Commission) |

| | |
|---|---|
| The government's Budget 2021 initiative, also known as the MySDG Trust Fund, calls for the establishment of the Malaysia-Sustainable Development Goals (SDG) Trust Fund in partnership with the UN. Funding from various public and private sources will be methodically coordinated by the fund. As a result, a range of stakeholders can contribute to and take part in initiatives to ensure that the SDG is achieved by 2030 [31]. | Ministry of Finance Malaysia |
| The national sustainability agenda is strengthened as the first strategy under Budget 2022's Third Focus: A Prosperous and Sustainable Economy. As a result of Malaysia's commitment to achieving the Sustainable Development Goals (SDGs), the annual budget now takes into account the 17 SDGs. Additionally, green budgeting will be used to match the current year's budget with future budgets to make it easier to carry out initiatives and programmes for environmentally friendly development [16]. | Ministry of Finance Malaysia |
| Malaysia will become carbon-neutral by 2050, according to the YAB Prime Minister. Because of this commitment, reforms must be carried out in the nation for growth to be competitive on the international market and sustainable. To achieve the goal of carbon neutrality, Bursa Malaysia will advocate for the launch of the Voluntary Carbon Market (VCM) programme. This initiative provides a voluntary platform for trading carbon credits for owners of green assets and other organisations switching to low-carbon practises. Contrarily, BNM will offer a Low Carbon Transition Facility with a fund value of RM1 billion, based on a matching fund agreement with participating financial institutions, to help SMEs adopt sustainable and low-carbon practises like boosting the use of sustainable raw materials and renewable energy [16]. | Bursa Malaysia |
| The development of Malaysia's clean energy sector has been greatly aided by policies like the Green Investment Tax (GITA), Smart Automation Grants (SAG), and Net Energy Metering 3.0 (NEM 3.0). The NEM permits power bill credits for solar installations, producing alluring ROI promises. NEM Net Offset Virtual Aggregation (NOVA), the scheme's business quota, was swiftly oversubscribed, demonstrating its appeal. For business owners, the GITA and Capital Allowance (CA), which are eligible for tax breaks of up to 48 percent, are excellent motivators. Additionally, Bank Negara provided RM 1 billion to help small and medium-sized businesses (SMEs) adopt environmentally friendly and sustainable practises [34]. | Sustainable Energy Development Authority (SEDA) Malaysia |
| The Malaysia Renewable Energy Roadmap 2035 (MyRER), which will serve as a strategic framework for the nation to host a low-carbon power sector, was also completed by SEDA Malaysia on December 30. MyRER creates strategies to assist the government in reaching its stated objective of having 31% of installed capacity in the country come from renewable sources by 2025 [10]. | Sustainable Energy Development Authority (SEDA) Malaysia |
| The year 2021 was a watershed moment in government struggle against climate change. The Intergovernmental Panel on Climate Change (IPCCSixth)'s Assessment Report provides indisputable proof that climate change is real and has an influence on our daily lives, particularly among the most vulnerable members of our society (ASEAN State of Climate Change Report, 2021). In 2020, the government issued a tender for a 1400 MW solar power project, which is estimated to produce investments of 5 billion Ringgit (US$1.1 billion) [14]. | |

## 3. Discusion

The researcher summarized the data analysis in the details below:

- Energy crisis: From the gather data's, Malaysia currently in the face of transition from fossil fuels to RE power as it has been predicted that's conventional fuels will be depleted in 70 years but targeted the world energy also could deplete in 30 years. In order to meet Malaysia's Nationally Determined Contributions (NDCs), which were ratified during the Paris Agreement, only 10% of Malaysia's total energy consumption is currently made up of the use and deployment of renewable and alternative energy sources.
- Alternative energy sources in Malaysia: Alternative energy sources in Malaysia included hydro and marine, bioenergy, solar power, wind, and geothermal, according to data reviews. Hydro and marine power are the most commonly used RE sources in Malaysia, and solar power is becoming more prominent.

- Barriers of deployment of alternative energy: Three main barriers in order to deploy RE in Malaysia which is issued of approval processes and land access, financing, and feedstock availability for power generation (mainly for biomass projects).
- EEB: EEB refers to building has the potential to positive impact on the climate as well as the environment throughout its design, construction, or operation which is classified as Zero Energy Building (ZEB) and to include ISO50001 (Energy Management). The elements of EEB such as reduced energy consumption, reduced solar heat gain, capturing natural light, using RE sources, and ensuring adequate testing and maintenance.
- Digitalisation construction in Malaysia: Adopting digitalization could considerably improve the built environment. Digital technology provides data on behaviour, usage, failure models, performance indicators, emissions, and performance under stress. Currently, the Malaysian government is actively working on a national and community-specific digitalization strategy, plan, and programme.
- Government policies: There're several government policies concerning alternative energy in Malaysia such as National Building Energy Intensity (BEI) and Malaysia's Future Energy Landscape 2050 by Suruhanjaya Tenaga (Malaysia Energy Commission), Budget 21 and Budget 22 about the sustainability agenda by Ministry of Finance Malaysia, The Voluntary Carbon Market (or VCM) by Bursa Malaysia, Green Investment Tax (GITA), Smart Automation Grants (SAG), SEDA's Net Energy Metering 3.0 (NEM 3.0) and Malaysia Renewable Energy Roadmap 2035 (MyRER).

## 4. Conclusion

In conclusion, Malaysia is committed to tackling and combat issues of climate change by ratifying NDCs during the Paris Agreement as to promote the use of RE such as hydro and marine, bioenergy, solar power, wind, and geothermal but there are barriers to overcome which is issued of approval processes and land access, financing, and feedstock availability for power generation. In regards with EEB, the researcher suggested the idea of EEB to coordinate with RE by referring to the building has the potential to positive impact on the climate as well as the environment throughout its design, construction, or operation which is classified as Zero Energy Building (ZEB) and to include ISO50001 (Energy Management). The elements of EEB such as reduced energy consumption, reduced solar heat gain, capturing natural light, using RE sources, and ensuring adequate testing and maintenance. The government policies which supported the RE agenda like BEI, Malaysia's Future Energy Landscape 2050 by Suruhanjaya Tenaga, Budget 21 and Budget 22 about the sustainability agenda by Ministry of Finance Malaysia, The Voluntary Carbon Market (VCM) by Bursa Malaysia, SEDA's GITA, SAG, NEW 3.0 and MyRER programmes are all greatly useful in nurturing Malaysia's clean energy sector's growth. By integrating an effective building envelope and deploying energy-efficient and high-performing utilities that encourage lower levels of energy consumption, future buildings will place a greater emphasis on renewable and sustainable energy resources. The ecology and the economy can both benefit greatly from net-zero buildings, in the end. Alternatively, digital technology boosts output while reducing risks. It enhances teamwork, worker safety, and design accuracy in the construction sector, offering you a competitive edge.

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