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Green Building vs. Green Construction: Exploring Key Differences and Challenges for a More Sustainable Industry (A Narrative Review)

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ABSTRACT

The construction industry is a major contributor to a country's Gross Domestic Product; however, construction activities also result in high greenhouse gas emissions, energy consumption, and waste generation that negatively impact the environment. To overcome these practices, sustainable development has become a popular concept, with Green Building and Green Construction introduced to promote sustainability in the construction industry. This review aims to address critical research questions distinguishing the concepts of Green Construction and Green Building, providing a better understanding of green practices in the construction industry, including the key definitions and concepts that contribute to sustainable development and environmental protection. Additionally, this study explores the differences and similarities between Green Construction and Green Building, operationalising them and discussing the implications they have for building and construction practices. Furthermore, the review highlights the key drivers and challenges for establishing the terms Green Building and Green Construction, as well as their broader societal goals such as sustainability and environmental protection. This review also examines the benefits and drivers of green practices implementation in the industry, and recognises the development of established green rating systems to evaluate the green measures of building projects. By shedding light on these aspects, this study will enable stakeholders and key players in the industry to pay more attention and take proactive actions towards the future direction of sustainable development.

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1. Introduction

The construction industry has a significant impact on a country's economic growth and Gross Domestic Product, as well as indirectly affects the well-being of its population (Yusupdjanova & Asadova, 2021). Basic infrastructure, such as roads, airports, electricity, and communication utilities, are crucial for the development of society, other sectors, and industrial production and growth (Ibrahim et al., 2010). The demand for the construction industry is increasing due to population growth and urbanisation. Subsequently, this can negatively impact the environment if proper mitigation plans are not put in place (Jing et al., 2017). The continuation of unsustainable practices will result in the depletion of resources.

The environmental impacts of construction are significant and occur throughout the entire lifecycle of a building, including its construction, operation, and demolition (Ametepey & Ansah, 2014). The construction industry is a major contributor to global energy consumption and greenhouse gas emissions, with building production accounting for almost 40% and 19%, respectively (Bahramian & Yetilmezsoy, 2020; Cao et al., 2022; Xu et al., 2021). Additionally, the manufacturing and transportation of construction materials contribute to about 50% of total global carbon emissions (Lawrence, 2015). Construction waste production during the construction phase also poses significant environmental challenges, including soil infertility, air, water, and land pollution, with construction waste accounting for 45% to 65% of landfill waste (Darko & Chan, 2017; Lima et al., 2021).

Due to the environmental, social, and economic challenges caused by unsustainable practices, the three-bottom-line approach has been widely adopted to promote sustainable development (Jainudin et al., 2017; Nogueira et al., 2022). In this movement, the construction industry has introduced Green Building (GB) and Green Construction (GC), to promote sustainability. However, existing sustainable development studies frequently interchange the concept of GB and GC which confuses the industry in policy making, project implementation and sustainability assessments (Doan et al., 2017; Shurrab et al., 2019). GB focuses mainly on sustainable design, energy efficiency and operational performance, while GC focuses on sustainable construction processes, material selection and waste reduction throughout the project life cycle (Luo et al., 2022).

Despite the growing global efforts to promote sustainability in the construction industry, there are few challenges that persist its wider adoption such as most of construction projects are labelled as "green" without clear distinction between green building designs or sustainable construction practices. This ambiguity affects the policy development, certification process and the actual implementation in the industry (Darko & Chan, 2017; Luo et al., 2022). Other than that, although there several green rating systems established, challenges such as high implementation cost, insufficient expertise and inconsistent regulatory prevent wider adoption (Shurrab et al., 2019). Furthermore, most construction stakeholders are struggling to meet sustainability standards due to the unclear guidelines on GB and GC integration. In addition, the construction industry remains as one of the largest contributors to global carbon emissions which exacerbates climate change and causes shortage of resources (Bahramian & Yetilmezsoy, 2020). Due to the perception of high costs associated to green certifications and environmentally friendly materials, many developers and contractors are discouraged to fully undertake sustainability initiatives.

Therefore, to address these challenges, this review aims to provide a clear distinction between GB and GC and examine their respective roles in achieving sustainability goals. To fulfil this review, several critical research questions are developed, including:

- How can the fundamental principles and elements of green building and green construction contribute to sustainable results in the construction industry?
- How do the differences and similarities between green building and green construction affect building and construction practices?
- What are the challenges, key drivers, and potential implications of green building and green construction in achieving sustainability movement?

In order to answer these questions, this study adopts the traditional method of narrative review which is suitable to synthesis the wide range of existing knowledge and to provide quick, up-to-date references on specific topics and identifying research gaps from various sources (Basheer, 2022). The relevant literature was identified through several academic databases such as Scopus and Google Scholar using keywords such as "green building", "green construction", "sustainable construction" and "green rating systems". The articles are selected based on their relevance, academic rigour and contribution to understand green practices in the construction industry. The articles are then analysed the themes to highlight key differences, commonalities, benefits, challenges and implications of GB and GC practices in a wider context of sustainable development.

Through conducting an in-depth reviews of existing studies to answer the research questions, this paper seeks to bridge the knowledge gap and contribute to the body of knowledge to provide a full picture to the stakeholders and industry practitioners in understanding the prevailing green movement. Other than that, a clearer understanding on GB and GC can encourage the effectiveness of green policies, strategies and construction practices which further encourages the adoption of sustainable construction.

2. Benefits, Challenges and Drivers for Green Practices

2.1 Benefits of Green Practices in the Construction Industry

The adoption of green measures in construction projects can contribute numerous benefits to the economy of countries, the environment, and society. From Table 1 it is observed that the most mentioned benefits of green practices in the construction industry from literature are able to reduce construction waste, high efficiency in energy consumption and improved occupational health and safety. However, according to Coelho & De Brito (2012), in order to reduce construction waste generation on-site, the 3Rs (Reduce, Reuse, Recycle) rate should be at least 90% for building construction projects.

Furthermore, relying on renewable resources can reduce the energy during operational stages by up to 30% to 55% which subsequently reduces 10% of the operational cost of buildings and compensate for the upfront cost required for labour and technologies used (Ojo-Fafore et al., 2018; Ries et al., 2006; Zuo & Zhao, 2014). In addition, the occupational health and safety of the workers can be protected through the adoption of precast construction techniques which can also help to reduce hazards and injuries on construction sites as minimal work is carried out on-site (Amin et al., 2019). However, the level of safety precautions and management adopted on the construction site will also play a significant role.

Another benefit of green building is it can improve indoor environment quality (IEQ) through choices of materials, lighting features, ventilation features, and heating and cooling features (Geng et al., 2019; Zuo & Zhao, 2014). IEQ level is always related to the level of satisfaction of the building's occupants through their health and productivity (Zuo & Zhao, 2014). As occupants' productivity increases, economic development is also likely to improve (Kalkavan et al., 2021). However, a study found that some retrofitted green buildings increased health problems for the occupants through airways, nose, skin, and eyes. (Ortiz et al., 2020). In addition, some energy-saving buildings do not perform as intended, which can be due to the occupants' activities, knowledge, awareness, and technical issues.

Table 1 Benefits of Green Practices in the Construction Industry (Ranked based on most cited in literature)

No.	Benefits	References
1.	Reduces construction waste.	Danatzko et al. (2013); Drochytka et al. (2013); Eghbali et al. (2019); López-Guerrero et al. (2022); Panda et al. (2018); Yang et al. (2021); Yunus et al. (2019)
2.	Energy efficiency (about 30% to 55 %).	Chakravarthy et al. (2022); Lau et al. (2009); Ojo-Fafore et al. (2018); Ries et al. (2006); Zuo & Zhao (2014)
3.	Improves occupational health and safety.	López-Guerrero et al. (2022); Ojo-Fafore et al. (2018); Ries et al. (2006); Yunus et al. (2019); Zuo & Zhao (2014)
4.	Improves employee productivity (About 25%).	Ries et al. (2006) ; Zuo & Zhao (2014)
5.	Reduces buildings' operational costs (up to 10% compared to conventional buildings).	Ojo-Fafore et al. (2018); Ries et al. (2006)
6.	Water efficiency.	Yudelson (2009) ; Zuo & Zhao (2014)
7.	Resources efficiency.	Ojo-Fafore et al. (2018); Zuo & Zhao (2014)
8.	Occupants' satisfactory.	Ojo-Fafore et al. (2018); Zuo & Zhao (2014)
9.	High level of indoor environmental quality (IEQ).	Ojo-Fafore et al. (2018); Zuo & Zhao (2014)
10.	Reduces greenhouse gases emission.	Zuo & Zhao (2014)
11.	Lesser injuries during construction.	Dewlaney & Hallowell (2012)
12.	Improves visual comfort	Zuo & Zhao (2014)

2.2 Challenges and Limitations of Green Practices in the Construction Industry

Numerous studies have identified barriers to the adoption of green practices in the construction industry, despite the potential benefits to the economy, society, and environment. A comprehensive review of the literature has identified 20 common barriers, which are categorised as cost, information and knowledge, workforce, client and market, government-related, and construction time (Table 2).

The table depicts cost as the major barrier to adopting green practices. Stakeholders are concerned about the high initial cost of green technologies, which are often not produced locally. The fear of a long payback period further deters their investment in green practices. In developing countries, the main challenges to adopting green practices are often related to cost and time, rather than knowledge and information (Azami et al., 2018). Additionally, green practices may be more widely adopted in developing countries if the government provides incentives or subsidies (Chang et al., 2016). Lack of accuracy in lifecycle cost analysis for green products makes the industry reluctant to invest in such technologies (Arif et al., 2009). In this regard, the government plays a crucial role in promoting green practices by providing appropriate incentives, subsidies, and other forms of support.

The second most reported barrier to the wide adoption of green practices is insufficient information and knowledge. Despite the growing awareness of green practices, the industry is still unfamiliar with the application, and stakeholders may be reluctant to change due to concerns about project schedules, rising costs, and performance (Kim et al., 2020). The lack of expertise and green suppliers in the construction industry is another significant barrier to green practice. While the construction industry requires a high number of workers, there is a shortage of well-trained personnel and experts in this particular field, especially in developing countries (Durdyev et al., 2018). A recent review study conducted found that green buildings do not perform as expected as per design in terms of energy consumption and indoor environmental quality (Geng et al., 2019). Therefore, it is crucial to address the shortage of expertise and well-trained personnel in the construction industry to promote and achieve the successful adoption of green practices.

The lack of interest and demand from clients and the market is a reported barrier to green practice. Stakeholders often believe that current methods are sufficient for project completion, leading to reluctance in adopting green practices that may prolong construction duration. This integration of building technologies and interactions between different green personnel can cause delays if not properly managed (Hwang & Ng, 2013). Existing review studies show that the lack of enforcement and lack of systematic tools are the barriers to green practice. Lack of enforcement and systematic tools to evaluate green practices during the construction stage also pose significant challenges (Luo et al.,2022). The construction industry lacks the tools to properly evaluate green practices during construction, which may cause contractors to shy away from adopting green practices. Therefore, there is a need for the government to provide appropriate tools and financial institutions to support and motivate contractors to practice green during the construction stage (Hammond et al., 2020; Saleh & Al-Swidi, 2019). Additionally, studies have shown that green building construction consumes almost 10% more time compared to conventional buildings of the same size and characteristics (Hwang & Leong, 2013). Thus, the contractors perceived there are more risks to adopt green construction practices.

Although extensive research has been conducted on the challenges of green building adoption from various perspectives, the specific barriers to green construction practices, particularly during construction phase remain underexplored in the current literature. Luo et al. (2022) also reported similar findings in their review study. It is crucial to address these barriers to promote the widespread adoption of green practices in the construction industry. By doing so, we can take advantage of the numerous benefits that green buildings and construction projects offer, including reduced energy consumption, improved indoor environmental quality, and reduced construction waste.

Table 2 Barriers to Green Practices in the Construction Industry (Ranked based on most cited in literature).

No.	Barriers to Green Practice in the Construction Industry	References
	Cost	
1.	High initial cost	Abdelaal & Guo (2021); Ahn et al. (2013); Azami et al. (2018); Chan et al., (2014); Darko & Chan (2017); Durdyev et al. (2018); Chakravarthy et al. (2022); Khan et al. (2018); Kim et al. (2020); Luthra et al., (2015); Roslee et al. (2022); Samari et al., (2013); Shi et al. (2013)
2.	Lack of credit resources	
3.	Long pay-back return	
4.	Risk of investment	
5.	Economic feasibility	
	Information and Knowledge	
6.	Lack of information and knowledge	Ahn et al. (2013); Berawi et al. (2019); Chan et al. (2014); Darko & Chan (2017); Durdyev et al. (2018); Keleş et al. (2022); Khan et al. (2018); Kim et al. (2020); Roslee et al. (2022); Shi et al. (2013); Sichali & Banda (2021)
7.	Lack of awareness	
8.	Poor collaboration between stakeholders	
9.	Uncertainty	
	Workforce	
10.	Lack of green suppliers	Berawi et al. (2019); Chan et al. (2017); Chan et al. (2018); Durdyev et al. (2018); Chakravarthy et al. (2022); Kim et al. (2020); Shi et al. (2013)
11.	Lack of expertise	
12.	Lack of technical advancement	
	Client & Market	
13.	Lack of interest and demand	Darko & Chan (2017); Durdyev et al. (2018); Chakravarthy et al. (2022); Khan et al. (2018); Kim et al. (2020); Luthra et al. (2015); Samari et al. (2013)
14.	Passive culture	
15.	Lack of social acceptability	
	Government	
16.	Lack of incentives	Darko & Chan (2017); Durdyev et al. (2018); Khan et al. (2018); Kim et al. (2020); Roslee et al. (2022); Samari et al. (2013)
17.	Lack of enforcement	
18.	Lack of systematic tools	
19.	Lack of promotion	
	Time	
20.	Longer duration of construction time	Azami et al. (2018); Shi et al. (2013)

2.3 *Drivers for Going Green in Construction Industry*

To implement green practices, the construction industry faces various challenges, including lack of knowledge, high cost of green technologies, lack of awareness, and limited government enforcement, which have been discussed in the previous sections (Abdelaal & Guo, 2021; Azami et al., 2018; Darko & Chan, 2017). However, these obstacles can be effectively addressed through targeted drivers that promote and facilitate green practices across the industry, In this review, 18 possible drivers to achieve high green practices are collected from previous studies.

For instance, the main barrier to sustainable construction is the high cost of sustainable construction adoption. As shown in Table 3, the financial incentive is one of the top three drivers in achieving sustainable construction. The incentives provided can significantly cover the high initial investment in green technologies. Wong & Abe (2014) surveyed 436 green experts in Japan and it shows that market incentives can promote GB projects among stakeholders. In Canada, incentives such as tax benefits, loans, grants and rebates are effective in promoting green buildings in the country (Rana et al., 2020). Other than that, in their study, Kumar et al. (2024) highlighted those incentives such as tax breaks, fee discounts and rebates can effectively encourage the adoption of green building technologies. Thus, providing green subsidies, financial incentives, exemption on environmental taxes and carbon trading can encourage the industry in the adoption of green construction technologies (He & Chen, 2021; Olubunmi et al., 2016; Yang et al., 2021) although the effective type of incentives provided is still undefined.

The second most cited driver recorded by literature is the awareness and demand for greener construction methods to address the barrier of shortage on expertise and lack of awareness in green practices through various training programs to produce more experts in this field (Monahan et al., 2014). Additionally, joint efforts with academic institutions can provide early exposure and encourage research and development in green innovations (Chan et al., 2014). These efforts are highly essential for the successful implementation of new technology and construction method related to green practices in the construction industry.

Moreover, the lack of market and demand for sustainable green construction is a major barrier recorded in literature as discussed in previous section (Darko & Chan, 2017; Ogunmakinde et al., 2016). Previous studies in developing countries have shown that developers are more motivated to practice sustainable construction when there is high demand in the market (Chan et al., 2014). This issue can be tackled through public awareness and increasing the visibility of the long-term benefits of green practices in the construction industry (Darko & Chan, 2017; Samari et al., 2015). With high demand, stakeholders are more confident in implementing GB and GC as they are concerned about the high capital costs associated with green technologies.

As shown in Table 3, the first driver to go green is government policies and regulations to address the weak policy enforcement barrier as mentioned in the previous section. In this matter, the government plays a crucial role in the wide adoption of sustainable construction (Darko et al., 2017; Zhang, 2015). Through strict law enforcement, it can change the mindset of the stakeholders (developers, architects, consultants, contractors, and suppliers) to comply with rules and regulations (Chan et al., 2018) in terms of construction waste management and energy efficiency. Other that than, it is also an effective means of indirectly encouraging green measures adoption while also raising awareness in building projects (Arif et al., 2012).

Table 3 Drivers for Going Green in Construction Industry (Ranked based on most cited in literature).

No.	Possible Drivers	References
1.	Government policies and regulations	Abidin & Powmya (2014); Agyekum et al. (2022); Arif et al. (2009); Murtagh et al. (2016); Udawatta et al. (2015); Wang et al. (2014); Yang et al. (2021); Pitt et al. (2009)
2.	Awareness and demand	Pitt et al. (2009); Abidin & Powmya (2014); Andelin et al. (2015); Chan et al. (2014); Murtagh et al. (2016); Wang et al. (2014)
3.	Financial incentives	Pitt et al. (2009) Abidin & Powmya (2014); Chang et al. (2016); Udawatta et al. (2015); Yang et al. (2021)
4.	Environmental awareness	Murtagh et al. (2016); Udawatta et al. (2015); Wang et al. (2014)
5.	The high return on investment	Agyekum et al. (2022); Pitt et al. (2009)
6.	Conservation of resources	Agyekum et al. (2022); Ahn et al. (2013)
7.	Lower operating cost	Andelin et al. (2015); Arif et al. (2009)
8.	Green Building Rating Tools	Murtagh et al. (2016); Udawatta et al. (2015)
9.	Corporate social responsibility	Arif et al. (2009); Pitt et al. (2009)
10.	Waste Minimisation	Ahn et al. (2013); Arif et al. (2009)
11.	Improve indoor environmental quality (IEQ)	Ahn et al. (2013)
12.	Long term investment	Abidin & Powmya (2014)
13.	Increase productivity	Andelin et al. (2015)
14.	Corporate image	Andelin et al. (2015)
15.	Design quality	Murtagh et al. (2016)
16.	Business Opportunity	Agyekum et al. (2022)
17.	Knowledge and information	Murtagh et al. (2016)
18.	Sustainable technology	Wang et al. (2014)

Another driver that encourages the practice of sustainable construction is the target to provide environmental awareness towards GB and GC. Although environmental awareness is not a popular driver in the adoption of sustainable construction, its significant impacts cannot be ignored. Improvements in indoor environmental quality (IEQ) can increase the productivity of office or residential occupants (Geng et al., 2019; Mujan et al., 2019). The use of green building technologies and renewable energy resources is vital in achieving sustainable construction, according to Zuo & Zhao (2014). Energy efficiency significantly reduces the operating cost of buildings, motivating stakeholders to adopt green features in their building designs.

From the literature, it can be observed that government policies and regulations, awareness and demand and financial incentives are the top drivers to encourage green practices adoption in the construction industry. Hence, more proactive actions by respective key players can be taken to expose and convince the stakeholders on going green.

3. Current Status of Green Practices in the Construction Industry

3.1 Green Ratings: Understanding the Different Certification Systems

In the direction of sustainable development, green rating systems are introduced to evaluate and rate construction projects (i.e., buildings and infrastructure) to achieve the goals of sustainable development. Various Green Building Rating Systems (GBRS) have been introduced globally over the past two decades to certify and rate green building projects (Awadh, 2017; Doan et al., 2017; Shan & Hwang, 2018). GBRS are typically customized based on the specific needs of each country (Shan & Hwang, 2018).

The first GBRS, Building Research Establishment Assessment Method (BREEAM), was introduced in the 1990s and gained popularity in the 2000s (Shan & Hwang, 2018). In 2005, Building and Construction Authority (BCA) in Singapore introduced BCA Green Mark as a benchmark to differentiate and evaluate the performance of buildings in practicing environmental design and performance (Hwang et al., 2016; Hwang et al., 2018). In 2006, both China and the UK introduced standards to assess sustainability performance (Yu et al., 2015; Zhang et al., 2017). Following the example of Singapore's Green Mark, Malaysia introduced its own GBRS, the Green Building Index (GBI), to evaluate the environmental design (Nusa et al., 2015) and performance of buildings (Illankoon et al., 2017).

The development of green rating systems is not limited to building projects, as there are also rating systems for infrastructure works that aim to reduce environmental impacts from transportation and highway construction. Table 4 presents the criteria considered in existing green rating systems for both building and infrastructure projects from different countries. According to the table, energy, indoor environment quality, resources and materials, water efficiency, and sites are the top five essential criteria for both building and transportation categories. These findings are consistent with previous studies that analysed current green rating systems (Shan & Hwang, 2018; Singh, 2018).

However, it is crucial to highlight that the existing green rating systems for construction projects primarily focus on the initial and operational stages of buildings, with minimal consideration of the construction procedure and overlook the significant environmental impacts of the construction activities (Sandanayake, 2016; Dubey et al., 2023; Chodnekar et al., 2021). This is likely due to the shorter lifecycle of the construction stage compared to the operational stage of buildings (Ngwepe & Aigbavboa, 2015). However, it is important to note that the construction stage has a significant impact on the environment, including high consumption of water and electricity, high waste generation, and high environmental impacts (Hong et al., 2015; Khasreen et al., 2009; Lima et al., 2021; Ngwepe & Aigbavboa, 2015).

Given the substantial footprint of construction activities, there is a need to establish rating systems that specifically consider green practices during the construction stage to facilitate a greener construction procedure. This research gap has led to the need for a more comprehensive rating system incorporating specific construction sustainability parameters (Dubey et al., 2023). Existing study proved that by integrating Lean Construction principles with green building practices can improve efficiency and sustainability at the construction stage, although the understanding of the combined benefits is still limited (Aristizábal-Monsalve et al., 2021). Other than that, project management skill is important in achieving green construction objectives such as staff management based on expertise and construction performance documentation, processes and practices (Wu & Low, 2010). By addressing these aspects in rating systems can provide a more holistic sustainability assessments, raise awareness and promote exposure for the implementation of green construction practices.

Table 4 Comparison of Criteria in Existing Green Rating Systems

Category	Green Rating Systems	Criteria
Building	**Building Research Establishment Assessment Method (BREEAM)** (Doan et al., 2017)	Management, Health and Well-being, Energy, Transport, Water, Material, Waste, Land Use & Ecology, Pollution, and Innovation.
	Leadership in Energy and Environmental Design (LEED) (Doan et al., 2017)	Integrative Process, Indoor Environment Quality, Energy & Atmosphere, Location & Transportation, Water Efficiency, Material & Resources, Sustainable Sites, Regional Priority, and Innovation.
	Comprehensive Assessment System for Built Environment Efficiency (CASBEE) (Illankoon et al., 2017)	Indoor Environment, Service Quality, On-Site Environment Energy, Resources & Material, and Off-Site Environment.
	Green Star NZ (Doan et al., 2017)	Indoor Environment Quality, Energy, Transport, Water, Material, Land Use & Ecology, Emission, and Innovation
	BCA Green Mark (Ting, 2012)	Energy Efficiency, Water Efficiency, Environmental Protection, Indoor Environmental Quality, and Other Green Features.
	Green Building Index (GBI) (Algburi et al., 2016)	Energy Efficiency, Indoor Environmental Quality, Sustainable Site Planning & Management, Materials and Resources, Water Efficiency, and Innovation
Infrastructure	**Green Road Rating Systems** (Clevenger et al., 2013)	Energy efficiency, Environmental Review Process, Cost Analysis, Lifecycle Inventory, Quality Control Plan, Noise, Waste, Pollution, Pavement, and Site.
	Green Highway Index (GHI) (Nusa et al., 2015)	Energy Efficiency.
	BE2ST-in-Highways (Nusa et al., 2015)	Pavement Recycle Materials
	Green Leadership in Transportation and Environmental Sustainability (GreenLITES) (Clevenger et al., 2013)	Energy, Atmosphere, Water Quality, Material Resources, Site, and Innovation.
	Sustainable Infrastructure Rating System (ENVISION) (Clevenger et al., 2013)	Water, Energy, Landscaping, Transportation, and Information.
	Energy Efficient Index (EEi) (Nusa et al., 2015)	Energy and Atmosphere
	Infrastructure Voluntary Evaluation Sustainable Tools (INVEST) (Clevenger et al., 2013)	Project Lifecycle (i.e., Planning and Design; Project Development; Operations, and Maintenance)
	Illinois-Livable and Sustainable Transportation (I-LAST) (Clevenger et al., 2013)	Planning, Design, Environmental, Water Quality, Transportation, Lighting, Materials, and Innovation

3.2 Future Outlook: Advancements and Innovations in Sustainable Construction

The construction industry has made significant progress in adopting green construction practices to minimize negative environmental, social, and economic impacts. While some industries are still transitioning towards Industry Revolution 4.0, the world is gradually moving towards Industry Revolution 5.0 (IR 5.0), where the collaboration between humans and machines is crucial (Paschek et al., 2019). Sustainable development concerns have spurred research and development in the construction industry, leading to the development of technologies that support sustainability throughout a building's lifecycle by reducing carbon emissions, embodied energy of materials, transportation systems, and material wastage. Studies have shown that green building technologies can reduce energy consumption by 30% compared to conventional buildings (Chakravarthy et al., 2022).

However, previous reviews on green the movement in the construction industry (Cao et al., 2022; Darko & Chan, 2017; Luo et al., 2022) are lacking in information on the evolution of technologies and technique in construction technologies and techniques and their potential benefits for green practices. Hence, this review explains how newly introduced construction technologies and techniques can promote sustainable construction projects. The government plays a significant role in providing exposure and incentives to the industry to ensure that these technologies are adopted for all types of construction projects, as the high cost of green technologies is a major challenge (Chan et al., 2017). In addition to high costs, insufficient promotion, interest, and market demand are barriers to green technology adoption (Wong & Voon, 2020).

3.2.1 Building Information Modelling (BIM)

BIM technology has been increasingly utilized by the Architecture, Engineering, and Construction (AEC) industry for sustainable projects (Aryani et al., 2014). By utilizing BIM models, necessary supplies, equipment, capital requirements, and schedule planning for construction can be identified in advance (Diaz-Sarachaga et al., 2017). BIM tools are intelligent and can analyse building performance, provide simulation and visualization of designs, making them useful for building projects that require data on energy efficiency and sustainability (Manzoor et al., 2021). In addition, BIM can improve the design process, construction process, and management of green buildings, benefitting architects and contractors (Olawumi & Chan, 2018).

Previous studies have shown that BIM technology plays a significant role in reducing construction waste production and improving design efficiency by minimizing disputes between stakeholders (Manzoor et al., 2021; Olawumi & Chan, 2018). BIM has also been reported to help improve the design process and enhance communication to produce design quality and work efficiency (Huang et al., 2021). Drawing discrepancies caused by disputes between stakeholders is causing waste in materials and significantly affects the construction time and cost due to hacking and rebuilding works. However, the industry is still hesitant to adopt BIM in construction projects due to various reasons such as unstandardized BIM software, inefficient interaction between construction software and BIM software, lack of BIM training for employees, ineffective management by the government and enterprises, high initial costs and unforeseeable investment returns, and inadequate guarantee and guidance (Criminale & Langar, 2017; Huang et al., 2021).

3.2.2 Industrialised Building System (IBS)

Industrialised Building System (IBS) is an alternative construction method that minimizes on-site work and can contribute to sustainable construction. IBS involves manufacturing building components on or off-site in a controlled environment and then assembling them at the construction site (Ali et al., 2018; Saleh & Alalouch, 2020; Zairul, 2021). IBS can be used for infrastructure works, high-rise, and low-rise buildings. Conventional construction methods produce massive amounts of construction waste, including concrete, steel, and timber materials, which IBS can help to reduce (Muhaidin & Chan, 2018). In Oman, the same waste problem has made IBS the main construction method in the country (Saleh & Alalouch, 2020). Poor workmanship quality and overwhelming management control in conventional construction methods are other factors that encourage IBS adoption (Yunus et al., 2019).

Sustainability can be delivered through IBS by reducing construction waste, minimising the consumption of sources, increasing the quality of buildings, and improving occupational safety and health (López-Guerrero et al., 2022; Yunus et al., 2019). IBS has been shown to reduce construction waste by 40% to 100% (Eghbali et al., 2019). According to Saleh and Alalouch (2020), IBS not only benefits the environment by reducing waste materials, but the components also have better quality due to their controlled manufacturing environment with the supervision of experts. This environment ensures that the on-site condition is cleaner with less debris. Additionally, the weather does not affect work productivity, as the components are prefabricated before being transported to the site for assembly. Despite its benefits for the environment, economy, and social life, IBS is not yet applied in every construction project. Insufficient knowledge and skill among workers, high initial cost issues, and limited IBS design are the obstacles to wider IBS adoption in the construction sector (Ali et al., 2018).

3.2.3 3-Dimensional Printing

Three Dimensional (3D) printing has been introduced about half a decade ago and is also named additive manufacturing (Labonnote et al., 2016). It has been widely applied to produce prototypes for medical and engineering purposes (Su & Al'Aref, 2018). Only recently has the construction industry started to adopt 3D printing as a means to reduce construction waste and promote sustainable construction. Studies have shown that 3D printing can reduce construction waste by 30% to 60% (Panda et al., 2018; Yang et al., 2018). Conventional construction method produces a significant amount of waste and is considered a negative impact on the environment, with formwork being a major source of waste due to high labor costs and material expenses (Hager et al., 2016). The popular technique in 3D printing is contour crafting where concrete is printed from a nozzle without trowelling blades (Kaszyńska et al., 2020). However, challenges still exist in adopting 3D printing in every construction project, especially in developing more holistic designs for the 3D printing approach (Labonnote et al., 2016).

3.2.4 Virtual Reality and Augmented Reality

Augmented Reality (AR) and Virtual Reality (VR) are technologies that have been around for a while but have only recently been adopted to assist in construction activities. AR integrates digital display with real-life display, while VR is a computer-generated simulation in which a person can interact with an artificial three-dimensional environment using an electronic device (Berryman, 2012; Hidayat & Prijotomo, 2017). In green building construction, VR can help to reduce the production of waste materials and increase design productivity by allowing architects to visualise real-life buildings conditions (Suryawinata & Mariana, 2022). By minimising discrepancies on-site, digital visualization can significantly reduce the chance of hacking and rectification work. From Table 5, it is observed that AR can contribute more to the construction industry, particularly in project management, since it can augment the real world by including additional unreal elements.

AR and VR are usually integrated with technology from BIM for refinement (Schiavi et al., 2022). Although AR and VR have been shown to increase work productivity and promote sustainable construction, several hurdles hinder their widespread adoption, including high costs, lack of expertise, technology maintenance, and unavailability (Ahmed, 2019). As a result, the full potential of AR and VR in the construction industry has yet to be realized. Despite these challenges, continued research and development in AR and VR have the potential to revolutionize the way construction projects are managed and executed. The future of construction lies in the integration of advanced technologies like AR and VR to enable more efficient, cost-effective, and sustainable construction practices.

Table 5 Contribution of AR and VR in The Construction Industry (Ahmed, 2019).

Augmented Reality (AR)	Virtual Reality (VR)
• **Project Scheduling** • **Progress Tracking** • **Worker Training** • **Safety Management** • **Time and Cost Management** • **Quality and Defects Management**	• Visualisation Tool • Worker Training Technology • Safety Management Tool • Quality and Defects Management

3.2.5 Green Materials

The use of recycled building materials is an effective way to reduce the environmental impact of construction activities while lowering material costs and promoting sustainability in construction projects (Sandanayake et al., 2020). Construction activities account for about 30% of greenhouse gas emissions, with transportation and production of construction materials accounting for 18% of these emissions (Lima et al., 2021). Therefore, selecting the appropriate materials is crucial during the initial stages of green building construction to avoid adverse environmental impacts (Singh, 2018). The usage of toxic materials for buildings may cause harmful health to the occupants. The conventional construction material, Ordinary Portland Cement, is a primary component of concrete, but its usage contributes to about 8% of the world's carbon dioxide emissions (Sivakrishna et al., 2020).

Various studies have been conducted to identify alternative materials that can replace or supplement conventional construction materials to ensure sustainable construction practices. Alternative materials, such as timber (Sandanayake et al., 2020; Stepinac et al., 2020), green concrete (De Luca et al., 2017; Deng et al., 2022; Gamage et al., 2011; Sivakrishna et al., 2020) and fibres (Al-Khafaji et al., 2021), have shown potential as sustainable materials for both low and high-rise buildings. These materials are renewable, produce low greenhouse gas emissions, and generate less waste, making them ideal for environmentally friendly construction. Ongoing studies continue to explore and develop sustainable materials to promote green building construction.

4. Green Building and Green Construction

4.1 Defining Green Building and Green Construction

To promote sustainability in the construction industry, two terms are introduced which are Green Building (GB) and Green Construction (GC). The term green building is defined by the US Green Building Council as "an effort to provide a comfortable living experience and reduce the damage to the ecology and environment in their entire lifecycle" (USGBC, n.d.). Other studies have defined GB as the most effective method in ensuring the sustainability of a building cycle by considering construction method that uses resources efficiently and is environmentally friendly (Keleş et al., 2022; Luo et al., 2022). According to Ur Rehman et al. (2017), the term GB covers the most crucial aspects of construction, such as being economical, environment-friendly, and preserving natural resources to meet current demand without compromising the demands of future generations. Cao et al. (2022) summarised various definitions of GB as high-quality buildings that provide comfort for residents with minimal pollution, lesser negative impacts on the environment, lower consumption of non-renewable resources, and low lifecycle costs. Therefore, GB not only focuses on the economy of the industry and the environmental impact of building projects but also takes into consideration the health and well-being of the residents.

On the other hand, the definition of Green Construction, according to Kibert (2016), is "creating and operating a healthy built environment based on resource efficiency and ecological design". The terms "green construction" and "sustainable construction" are also used interchangeably, as both deal with "the protection and restoration of human health and the environment through design, construction, operation, maintenance, renovation, and deconstruction" (EPA, 2016). Additionally, some studies define GC as on-site procedures that utilise scientific and technological management to conserve natural resources and minimize negative environmental impacts (Shi et al., 2013; Shurrab et al., 2019).

4.2 Green Building vs. Green Construction: Understanding the Key Differences

Studies have shown that terms such as "Green Building", "Green Construction", "High-Performance Building", "Sustainable Construction", and "Sustainable Design" are often used interchangeably, leading to confusion among stakeholders and researchers in discussing the concepts of GB and GC (Durdyev et al., 2018; Tathagat & Dod, 2015). Existing studies indicate that while the concept of GB and GC is similar in their aim to promote environmentally friendly construction and protect the health and well-being of society, they have different key focuses based on the life cycle of buildings. Table 6 summarises the key differences between GB and GC. GB focuses on the overall life cycle of buildings, with a particular emphasis on the operational stage, while GC focuses specifically on the construction stage (Luo et al., 2022; Ngwepe & Aigbavboa, 2015). Clients, architects, and consultants play a crucial role in every stage of a building's life cycle, as they are responsible for selecting construction materials, planning and designing the building's operational systems. Factors to consider in GB include lot design, preparation and development, resource efficiency, energy efficiency, water efficiency, and indoor environment quality (Singh, 2018). This highlights the emphasis on planning for the overall life cycle of buildings in GB.

On the other hand, the key focus of GC is on-site green practices during the construction phase of building projects, with main and sub-contractors playing crucial roles in the adoption of these practices (Shurrab et al., 2019). Proper management of energy usage (water, electricity, and fossil fuels), construction time, and waste disposal are important factors to consider in GC (Shi et al., 2013; Shurrab et al., 2019). By understanding the difference between GB and GC, each key player in the construction industry can take proactive action in adopting green practices. This can lead to a reduction in negative environmental impacts, improved health and well-being for society, and greater overall sustainability (Ngwepe & Aigbavboa, 2015).

Despite the growing interest in sustainable construction practices, previous research has shown that discussions on green practices in the construction phase are often lacking, with a tendency towards focusing on GB principles and practices (Ahn et al., 2013; Singh, 2018). This gap is largely due to the conventional perception that the buildings operational stage has longer life cycle period and has longer environmental impact compared to the short period of construction stage (Sandanayake, 2022; Gil-Ozoudeh et al., 2022). As a result, most academics and industry focus on operating energy efficiency and long-term construction performance and often overlooked the immediate and important significant environmental impacts produced during the construction stage. This underscores the crucial need for more research and guidelines to emphasise the sustainable practices during the construction phase itself.

Furthermore, while several studies have been conducted on GB adoption, technologies, rating systems, challenges, and awareness, there is still a lack of research on GC that focuses specifically on contractor management and green practices during construction (Luo et al., 2022; Shurrab et al., 2019). Although both GB and GC aim to promote sustainability, most of the existing literature focuses mainly on the operational outcomes and design strategies but limited attention to the green practices at the construction site itself. For instance, a study by Ahn and Pearce (2007) investigated contractors' experiences, expectations, and perceptions toward green construction, but the discussion was primarily focused on GB knowledge and practices rather than detailing actual green implementation during construction stage.

Another study by Rostami et al. (2011) discussed trends in green construction in Malaysia but did not consider the green measures taken by contractors during the construction phase. These studies demonstrate that although the awareness of the principles of GB is growing, the practical actual implementation of GC measures such as waste management, resource efficiency and on-site environmental control by contractors is still under explored. Therefore, there is a need for more research on GC to understand the GC practices, especially from the point of view of the contractors' management and green practices during construction to bridge the existing knowledge gap and support the industry in moving towards more sustainable construction methods (Luo et al., 2022; Shurrab et al., 2019).

Table 6 Summary of Key Differences Between Green Building and Green Construction.

Criteria	Green Building	Green Construction
Key Focus	Operational Phase	Construction Phase
Key Players	Clients, Architects, and Consultants	Contractors
Factors	• Lot design • Preparation and development • Resource efficiency • Energy efficiency • Water efficiency • Indoor environmental quality (IEQ)	Management on: - • Energy usage • Construction time • Waste disposal

4.3 The Scope of Green Building: A Lifecycle Approach

GB focuses on the building lifecycle and can be categorized into three stages: pre-building, building, and post-building, each having different environmental impacts (Singh, 2018). The seven important scopes in GB are energy, site, indoor environment quality, land and outdoor environment, material, water, and innovation, which aim to monitor and evaluate the environmental impact for each stage (Shan & Hwang, 2018).

During the pre-building stage, conventional construction materials that exploit non-renewable resources such as sand, aggregates, and steel can cause the depletion of resources without proper supervision and law enforcement (Ngwepe & Aigbavboa, 2015). Thus, GB aims to use alternative or green materials to control the usage of non-renewable resources by finding non-toxic materials.

Energy is crucial at all stages of a building's lifecycle, and during the pre-building stage, energy is required for mining, extraction, and transportation of raw materials, which can produce pollutants to the environment (Ngwepe & Aigbavboa, 2015). During the building stage, the operational and maintenance of buildings require a lot of energy, and the carbon emissions from types of machinery and air pollutants from construction activities can impact the environment (Darus et al., 2009; Doan et al., 2017). However, in existing GB rating systems, there is still minimal attention to finding alternative methods to reduce environmental impact during the construction stage.

The building stage has the longest lifecycle period up to over 50 years compared to the pre-building stage (Ngwepe & Aigbavboa, 2015). Hence, most GB rating systems are paying more attention to the building's performance in reducing energy consumption, and the buildings shall be able to regulate their energy or consume renewable energy resources such as solar power and rain harvesting (Singh, 2018). The indoor environmental quality (IEQ) is also crucial in GB due to people spending almost 90% of their days indoors, in which volatile organic compound (VOC) or ultrafine particles released in the air can cause health problems (Ortiz et al., 2020).

Life-Cycle Assessment (LCA) is a quantitative method to evaluate the potential environmental impact and support decision-making in sustainable development, including in the field of green building (Brusseau, 2019; Luo et al., 2022). The assessment considers the product's life cycle, from raw materials to manufacturing and processing procedures. LCA is also known as the "cradle to grave" method as it identifies products with minimal negative environmental impact, determines strategic planning, and promotes environmental formulation (Muralikrishna & Manickam, 2017a). Also, the process cycle of a product includes the extraction and processing of raw materials, recycling, reuse, and marketing. However, it is worth noting that the product is only assessed based on its embodied energy, with other factors such as transportation and installation being excluded. While several studies have identified alternative materials to replace conventional construction materials, environmental assessments on these materials remain incomplete.

4.4 The Scope of Green Construction: Focusing on the Construction Phase

The building lifecycle, as noted by Ngwepe and Aigbavboa (2015) and Singh (2018), includes material extraction, manufacturing, construction, operational, maintenance, demolition, and recycling. However, green construction (GC) focuses only on activities and management during the construction phase, as opposed to green buildings (GB), which consider the entire lifecycle. According to Chitkara (2014), construction involves building a facility or providing a service with predetermined performance goals to achieve a high-quality product within the completion period and allocated budget costs. Despite its shorter lifecycle compared to the operational phase, various environmental actions must be taken into account during the construction phase, as it produces high carbon emissions and waste generation (Darko & Chan, 2017; Lima et al., 2021).

During the construction phase, various types of machinery and heavy equipment are used to execute construction works such as soil excavation, piles boring, materials hoisting, and building components installation on site. The extensive usage of construction equipment can pollute the environment as it uses a high amount of fossil fuels and electricity during the construction stage (Fan, 2017; Waris et al., 2014). Burning fossil fuels can emit dangerous gases such as carbon monoxide, carbon dioxide, and nitrogen oxide. The rate of emissions from construction equipment is mainly determined by the type and condition of equipment (engine power, fuel quality, and engine rebuild), operating conditions (nature of the job, environment conditions, and site condition), equipment maintenance, and also equipment operations (Fan, 2017).

Therefore, it is crucial to select sustainable onsite construction equipment to achieve productivity and efficiency while minimizing environmental harm. The selection of equipment for construction works is mainly based on performance and cost, with environmental criteria not being a priority, as shown in a study conducted among Malaysian contractors (Waris et al., 2014). To address the issue of pollution caused by construction equipment, maintenance improvement and the use of "unmanned" machines with hybrid engines and lightweight materials are recommended (Fan, 2017; Naskoudakis & Petroutsatou, 2016). However, research in this area is still at an early stage.

Another major concern during the construction stage is the generation of construction waste (CW), caused by poor coordination and communication among stakeholders, design discrepancies, improper site planning and supervision, poor work ethics, and residual materials (Osmani, 2011). To reduce CW generation, proper waste management and confirmation of designs before construction work are crucial. CW management and research are guided by the 3Rs (Reduce, Reuse, Recycle), with project teams encouraged to forecast CW production and prepare a Waste Management Plan for pre-construction works (Osmani & Villoria-Sáez, 2019). Factors considered in predicting waste generation include the function and size of the building, typologies of structures, and the accumulation rate of CW generation over the entire project duration (Sáez et al., 2014).

In the construction industry, it is crucial to take environmental action to uphold the ideology of going green. The Environmental Impact Assessment (EIA) procedure is used to evaluate the environmental consequences and identify mitigation measures for green construction projects (Drayson et al., 2017; Onubi et al., 2020). The EIA system varies according to the suitability of the country (Suwanteep et al., 2016). The EIA report for construction purposes should include project descriptions, baseline data analysis of the land, water, air, noise, biological, socio-economic, and occupational health, anticipated impacts and mitigation measures, environmental monitoring program, risk analysis and disaster management plan, and Environmental Management Plan (Muralikrishna & Manickam, 2017b).

Despite the importance of EIA, the industry is still discouraged to practice EIA due to a lack of professional personnel and lenient laws against EIA offenders (Khosravi et al., 2019). Additionally, the lack of attention to construction operations in most LCA software has caused GC adoption to remain at an infancy level. To improve the environmental impact assessment of a product, Luo et al. (2022) suggest considering embodied energy, transportation-related energy, and energy used during construction activities.

5. Conclusion

This paper provides a comprehensive review of green building (GB) and green construction (GC) which emphasises on their differences, commonalities and individual contributions to sustainable development in the construction industry. Through positioning the GB and GC as the central pillars of green movement, this study seeks to improve the understanding of construction stakeholders and guide them for a more effective implementation of green practices. The important parameters highlighted in this review are: -

- GB and GC share the same goal of promoting sustainability through environmental, social and economic considerations. However, both have different scope in which GB focuses on the entire lifecycle of a building, from design stage to demolition, while GC is specifically concerned with the green practices during construction stage of building projects.
- One of the main challenges identified is the imbalance in focus between GB and GC in current industry practices. GB is often supported by established green assessment systems, while GC is often overlooked.
- The major benefits on going green in construction industry are able to reduce construction waste on site, efficient energy consumption and improves occupational safety and health.
- Cost, knowledge and workforce are the most reported challenges that hinders the wide adoption of green practices especially for GC.
- One of the main challenges for green construction is the lack of attention given to green measures during the construction stage with existing green rating systems are more focused on the operational stage and lifecycle of the buildings.
- Government policies and regulations is cited as the major driver in encouraging sustainable practices in construction industry among stakeholders.

This paper makes a clear distinction between GB and GV and helps the industry to understand the fundamentals of sustainable construction, which significantly able to provide awareness and improve the measures taken by the government and stakeholders. Strengthening this understanding is crucial to develop more effective policies, certifications and on-site practices. Furthermore, recognising the role of different stakeholders in all phases of project lifecycle, from designers to contractors, is essential to align sustainable objectives throughout the building process.

Although GB and GC can benefit the economy, environment, and society in many forms, the industry is still reluctant to adopt sustainable construction. Financial constraint and limitation on knowledge are among the major challenges that limits the wide adoption of GB and GC. Thus, the government is the key driver in providing exposure, training, financial incentives, and strict law enforcement to encourage the industry in adopting sustainable construction.

This paper also found that there is a significant research gap, particularly in terms of behavioural factors that influenced GC adoption among contractors. Thus, more targeted research is needed to investigate the contractors' knowledge, attitude and practice to ensure that green practices are also adopted in construction stage and not only in design stage. In addition, recognising the concept of both terms can fulfil the environmental needs in each building's lifecycle and achieve more global and lasting changes in the construction industry.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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