

Review

On the Path towards Sustainable Construction—The Case of the United Arab Emirates: A Review

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Abstract: The construction sector in the United Arab Emirates (UAE) is expanding substantially due to many variables, including strong economic growth, a swiftly growing population, and continuous modernization endeavors. As a result, the development of the construction industry is leading to adverse impacts on energy consumption and environmental conditions. The UAE government and policymakers have implemented significant initiatives to advance sustainable infrastructure, promote clean energy utilization, effectively manage construction and demolition waste (CDW), and foster green building development. These measures follow the nation's dedication to the Paris Agreement, which aims to decrease greenhouse gas (GHG) emissions. The article comprehensively examines the policies and practices implemented in this industrialized nation concerning sustainable construction. Moreover, the primary objective of this study is to evaluate the performance of the UAE in comparison to other countries within the Gulf Cooperation Council (GCC) concerning their accomplishments in sustainability. Additionally, the study seeks to integrate insights from the global community regarding sustainability policies, Sustainable Development Goals (SDGs), the effective management of CDW, and the implementation of green regulations that govern environmentally conscious construction practices. A comprehensive analysis of information sources from official websites, particularly those of the ministry and key government agencies, is conducted to better understand the current sustainability policies and treatment methods related to the management of CDW and green building regulations.

Keywords: sustainability policy; construction and demolition waste; waste management regulations; green building regulation



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1. Introduction

The built environment, comprising structures, transportation networks, infrastructure, and other anthropogenic elements in our vicinity, accounts for over 50% of the annual global extraction of materials and constitutes a substantial source of GHG emissions [1]. In 2015, the emissions of carbon dioxide (CO₂), resulting from the construction and operation of buildings, accounted for 38 percent (13.1 gigatons) of the total world energy-related emissions [2,3]. To tackle climate change and its negative impacts, on December 2015, international leaders at the United Nations Climate Change Conference (COP21) in Paris agreed to “substantially reduce global GHG emissions to limit the global temperature increase in this century to 2 °C while pursuing efforts to limit the rise even further to 1.5 °C and provide financing to developing countries to mitigate climate change, strengthen resilience, and improve climate adaptation” [4]. There was a reduction of around 10 percent in CO₂ emissions within the sector by 2020, resulting in a total of 11.7 gigatons emitted. The decrease in energy consumption can be mostly attributed to the impact of the

COVID-19 pandemic, which resulted in a reduced energy demand [3]. Additionally, ongoing initiatives to minimize carbon emissions in the power industry have also contributed to this fall. Furthermore, it is anticipated that the temporary decline in energy-related emissions from buildings and construction will be transitory, with a projected resurgence coinciding with the recovery of economies following the global pandemic [5]. Hence, it is imperative to expeditiously and substantially decrease GHG emissions originating from the building sector at a worldwide scale in order to achieve the objectives outlined in the Paris Agreement.

GHG emissions and sustainability have gained more attention in the 21st century due to natural events and scientific studies. The United Nations (U.N.) Brundtland Commission in 1987 defined sustainability as “meeting the needs of the present without compromising the ability of future generations to meet their own needs” [6]. To effectively implement the Paris Agreement, the worldwide buildings and construction industry must undergo a considerable decarbonization process to achieve near-complete carbon neutrality by the year 2050. Historically and presently, the building industry has adhered to a non-sustainable economic model that follows a linear approach known as “take, make, dispose of”. The linear paradigm does not facilitate the deconstruction and reuse of buildings and elements, rendering them obsolete upon the building’s end-of-life [7,8]. The primary determinants of sustainable design and construction were energy conservation, the enhancement of environmental quality, the protection of ecological resources, and the reduction in waste [9].

One of the prominent concerns within the building industry pertains to the generation of CDW at construction sites, which has emerged as a substantial global issue owing to its adverse effects on the environment. The absence of proper management undoubtedly leads to significant environmental repercussions when dealing with large amounts of building waste [10,11]. On a global scale, it is approximated that approximately 35% of the volumes of CDW generated is disposed of in landfills without undergoing any additional treatment. However, there is a growing trend toward recycling and reusing CDW, as initiatives are progressively being undertaken [12]. The Global Advancing Net Zero initiative aims to drive the building and construction industry toward achieving a built environment with zero carbon emissions and zero waste.

There was a notable increase in research and initiatives to enhance energy efficiency and mitigate environmental pollution to tackle the environmental issues caused by the built sector in the last decade. The notion of green buildings has been progressively formulated and advocated globally in response to the numerous challenges faced by the construction industry. Consequently, green building rating systems have been devised and implemented. Green buildings prioritize enhancing energy efficiency and mitigating construction’s adverse environmental and resource effects. The approach can incorporate tactics from several phases of the building life cycle, encompassing siting, design, construction, operation, maintenance, renovation, and deconstruction, to mitigate the adverse effects on energy, water, materials, and other natural resources. It can also potentially reduce various environmental pollutants, including waste, air, water, indoor heat islands, stormwater runoff, noise pollution, and other related issues [13].

Sustainable development holds significant importance for the UAE, given the nation’s substantial dependence on natural gas and the escalating need for air-conditioning and desalination. Consequently, the UAE has emerged as one of the largest per capita carbon emitters. The UAE government has been actively implementing various policies and practices to enhance sustainable development domestically and internationally. It is engaged in a concerted effort to forge a sustainable trajectory for the future. This endeavor encompasses a diverse array of policies, programs, and accomplishments across various domains, encompassing the attainment of net zero emissions.

The Construction Industry in the UAE and Its Effect on the Environment

Ever since the union of the Emirates under the leadership of the founding father, H. H. Sheikh Zayed bin Sultan Al Nahyan on July 1971, followed by Ras Al-Khaimah in 1972, the

country has focused on its people's economic growth and welfare. Over the past 50 years, the UAE has transformed its fishing, pearl-diving, and agriculture-based economy into a technologically advanced and competitive economy by becoming a global frontrunner in economic performance [14]. The UAE is laying the groundwork for the development and profitability of knowledge-based, future-oriented commercial sectors. Oil and its export trade, the high standard of living, the availability of job opportunities, no income tax, and other attributes make the UAE a prime destination for immigrants [14,15]. The UAE is now home to over 200 nationalities, and the population is rising. The population of the UAE will be close to 11 million in 2023, out of which 9 million are expatriates from all over the world [16]. The immigrant population growth and leisure tourism have led to rapid construction development in the UAE [17]. The past decade has witnessed a remarkable growth in urban development in the UAE. Modern cities have sprung up in the middle of the desert, linked by a vast network of first-class roads, and which communicate with the rest of the world through modern airports and ports [18]. Every year, the UAE government spends billions of US dollars on new buildings to improve the country's infrastructure. The UAE accounts for 29% of the GCC region's construction market, the second-highest proportion after the Kingdom of Saudi Arabia (KSA) [19].

Most of these projects are being built in the Emirates of Dubai and Abu Dhabi. According to the Dubai Statistics Center, 180,048 buildings were constructed in 2021 as part of its Urban Master Plan [20]. The UAE construction industry comprises commercial, residential, industrial, infrastructure, and transportation construction. The relatively new construction activities that have had a phenomenal expansion over the past decade primarily rely on expatriates from many origins and experiences. It is usual for stakeholders within the same project to have a very varied cultural background while simultaneously operating within the cultural framework of the UAE, which, among other factors, affects the performance and demand for various infrastructures [21].

The effect of this urbanization and economic growth is a steep increase in CO₂ emissions in the country [22,23]. In 2020, the percentage of the world's total CO₂ emissions attributable to energy use in buildings and construction stood at 37%, compared to other sectors [2]. The typical adverse effects of construction activities include the emission of air and water pollutants, the modification of soil, the consumption of resources, and the production of waste [24].

Figure 1 illustrates the CO₂ emissions of several countries in 2021, measured in million tons [25]. However, the inclusion of CO₂ emissions per capita as an alternative metric is noteworthy. Qatar ranks among the top three countries, with 38.2 tons, closely followed by the UAE, with 22.4 tons [26]. The combustion of fossil fuels, including oil, gas, and coal, which account for over 75% of worldwide energy production, is recognized as one of the primary contributors to CO₂ emissions [27]. To reduce concentrations of GHGs and to mitigate the potentially devastating impacts of climate change, various measures can be applied, including safeguarding the natural systems that absorb GHGs, reducing emissions caused by human activities, adopting energy-efficient practices, promoting renewable energy sources, and implementing carbon capture, trading, and storage mechanisms [28].

The UAE exhibits similarities to highly developed nations, yet there remains room for development in addressing SDG challenges concerning the environment, consumption, and production. According to the 2023 SDG index on ranking and score, the UAE currently has the 79th position out of 166 countries with a score of 69.7 and still faces significant challenges in relation to its performance on the 17 SDGs [29]. Figure 2 illustrates the SDG dashboard of the UAE. The score has the potential to be regarded as a quantifiable representation of the level of achievement toward the SDGs, expressed as a percentage. A score of 100 signifies the successful attainment of all SDGs [29]. Significant challenges remain in renewable energy share in total final energy consumption, CO₂ emissions from fossil fuel combustion and cement production, and CO₂ emissions embodied in fossil fuel exports. Another major challenge for the UAE is that buildings have shorter life spans when compared to other countries. The shorter life span of buildings also results in many

environmental issues, including generating more CDW. The UAE's massive urbanization resulted in tons of CDW [30–32].

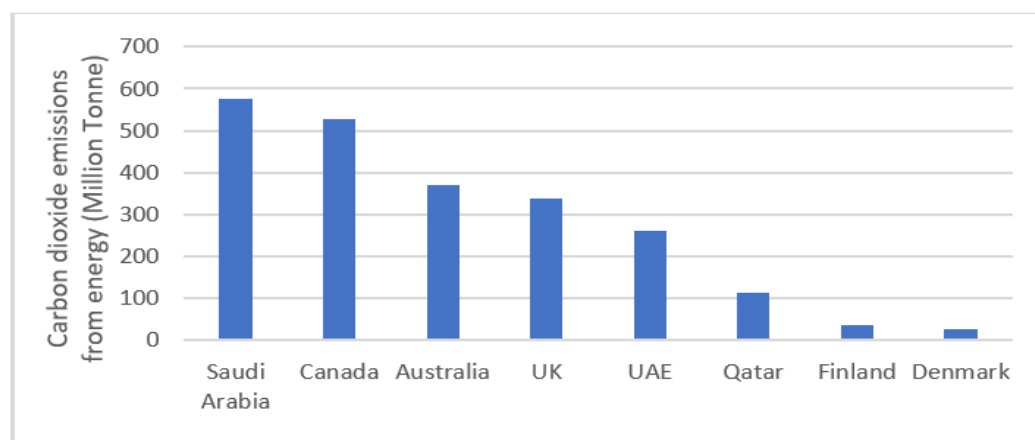


Figure 1. CO₂ emissions from energy [25].



Figure 2. SDG data of the UAE [29].

Nevertheless, the government and policymakers of the UAE are making substantial investments in the reconfiguration of the currently built sector in a more sustainable manner. This is being achieved through the utilization of sophisticated technologies and the implementation of novel business models. The primary objective of these efforts is to enhance economic growth while simultaneously addressing sustainability objectives. Through the implementation of policies, the government is making strides toward achieving its goal of zero emissions as outlined in its Net Zero 2050, Vision 2021, and circular economy policies. These efforts include the adoption of sophisticated recycling processes for CDW as well as the enforcement of green building regulations. These efforts are aimed at fostering the development of sustainable construction practices and the effective management of CDW, in line with the ambitious objective of achieving net zero emissions and diverting waste from landfills [33,34].

The purpose of this review paper is to analyze the range of sustainability initiatives, policies, strategies, legislation, and green construction rules that have been adopted by the UAE over a period of time. Additionally, it aims to assess the UAE's regional and international performance in these areas. This study aims to evaluate and compare the sustainability performance of the construction sectors in the UAE by analyzing key metrics, including energy consumption, carbon emissions, and waste generation. The paper is structured as follows. Section 2 explains the methodology adopted in this study. Section 3 provides a comprehensive analysis of the sustainability policies and initiatives that have been adopted by the UAE while also evaluating the performance of the UAE in relation to

other countries in the GCC. The section additionally seeks to derive insights for the UAE by examining the experiences of other nations that have demonstrated superior achievement in achieving the SDGs. Section 4 of this paper discusses the present data pertaining to CDW in the UAE, as well as the legislative measures and methodologies employed for the treatment of CDW inside the nation. This section also aims to compare its success with that of other GCC countries while seeking to glean ideas by reviewing the experiences of other states. Section 5 delves into the green construction regulations that have been established inside the country. This research investigates the performance of obtaining worldwide LEED certification in relation to other countries within the GCC while also providing a comprehensive examination of the green construction standards implemented by various countries across the globe.

The UAE, similar to several other nations, encounters limitations in terms of available resources. Conducting studies on sustainability initiatives and policies enables academics to assess the efficacy of a nation's resource management practices and their level of efficiency. The amount of construction waste is significant in the UAE, and the authors have attempted to convey the statistics from the federal department through the research literature. Gaining a comprehensive understanding of these activities and policies enables academics to evaluate their effectiveness and propose enhancements. This information has the potential to inform policy modifications or the development of new policies.

2. Research Methodology

For this study, a qualitative methodology was carefully selected to thoroughly examine and acquire a deep understanding of the existing sustainability policies, regulatory framework, CDW management procedures, and green building regulations in the UAE. The approach utilized in this review study entails a thorough and methodical analysis of the extant literature concerning sustainability policies, construction waste management, and green building laws. The research methodology employed a systematic and iterative process to collect, evaluate, and integrate various scholarly articles, governmental publications, and industry standards. The first phase entails developing a search strategy that incorporates pertinent keywords and databases, such as academic repositories, research databases, and reputable websites pertaining to sustainable construction techniques.

The Scopus database was employed to conduct a comprehensive investigation into the present condition of sustainability, CDW, in the UAE. The utilization of the search terms 'Sustainability' and 'UAE Construction Industry' resulted in the retrieval of 44 scholarly publications, whilst the combination of 'Waste Management' and 'UAE Construction Industry' provided 13 relevant papers. The main emphasis of these materials is to provide a comprehensive understanding of the management of construction waste in the UAE and the adoption of environmentally friendly building methods. Nevertheless, it is important to highlight that there is a notable lack of scholarly literature on "Sustainability Policy" in the context of the "United Arab Emirates Construction Industry". The prevailing body of academic literature in this field primarily focuses on supply chain management rather than offering a comprehensive analysis of the UAE government's and local authorities' sustainability policies to facilitate the implementation of integrated waste management practices, which are essential for the nation's sustainable development.

3. Sustainability Initiatives and Policies in the UAE

The policy environment surrounding the reduction in carbon emissions in the global building and construction sector is constantly evolving. In recent times, there has been notable advancement in the realm of buildings and construction regulations. This evolution is driven by various frameworks, including the Nationally Determined Contributions (NDCs) and the United Nations Framework Convention on Climate Change (UNFCCC) established in 1992. These NDCs are dependent on the individual commitments made by countries to fulfill the objectives of the Paris Agreement in 2015 [35]. Additionally, national policies and measures, such as building codes and energy efficiency programs,

also contribute to shaping this policy landscape. Currently, a significant majority of nations, over 80 percent, incorporate buildings as integral components of their NDC action plans. This percentage has witnessed an increase from roughly 69% in the year 2020 [2,3].

The UAE became an official party to the UNFCCC to facilitate its global responsibility toward climate change in 1995. To tackle the environmental issue, over the recent years, the UAE has made significant progress in addressing the complexities associated with energy and climate change and the strategic agendas of individual Emirates. Since 1989, when it accepted the Vienna Convention for preserving the ozone layer, the UAE has been dedicated to combating climate change. The UAE formed the Supreme Committee of Environment (SCE) in 1975, which later developed into the Ministry of Climate Change and Environment in 2016 to achieve sustainable development and retain the UAE's position as a regional and worldwide leader of action [36,37]. In 2005, the UAE acceded to the Kyoto Protocol [38]. The UAE Green Growth Strategy, known as the "Green Economy for Sustainable Development", was established in 2012, marking the ratification of the Doha Amendment under the Kyoto Protocol, followed by the UAE Green Agenda 2015–2030 in 2015 with an implementation framework in Green Growth [38].

To propel the region to be at the forefront of the renewable energy sector, in 2009, the UAE became a member and host of the International Renewable Energy Agency (IRENA) [39] with its headquarters in Masdar city in UAE, one of the world's first carbon-neutral, zero-waste cities powered by renewable energy [40]. To strive for a sustainable future, in 2011, the UAE launched a national development planning blue-print called the UAE Vision 2021 and also became host to the Global Green Growth Institute (GGGI—regional office), a treaty-based international, inter-governmental organization founded to support and promote green growth with its headquarters in the capital city [41]. Since 2015, subsequent to the ratification of the Paris Agreement, the UAE has experienced a notable augmentation in its sustainability policies and green growth initiatives, with a specific emphasis on infrastructure, energy, and the environment. Figure 3 shows the launching timeline for various sustainability policies in the UAE.

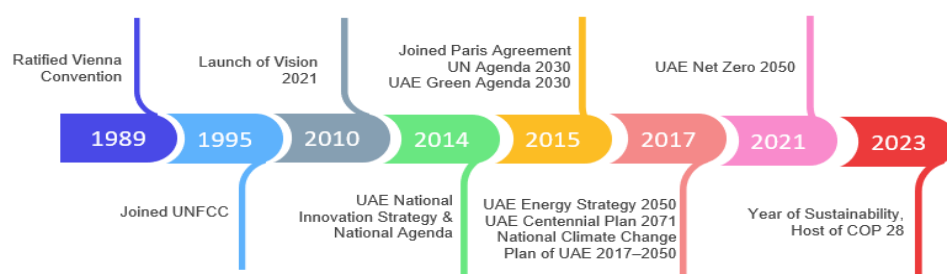


Figure 3. The UAE's primary sustainability initiatives timeline (authors' contribution).

The UAE consistently reaffirms its global leadership in environmental initiatives through annual events like Word Green Economy and Abu Dhabi Sustainability Week, attended by several state leaders and government officials from across the globe [42]. Moreover, the UAE's environmental commitment extends beyond these annual events. Hydrogen Leadership Roadmap, a comprehensive national roadmap to promote domestic, low-carbon sectors, contributes to net-zero ambitions and makes the country a competitive hydrogen exporter [43].

The UAE will have a landmark year in 2023. President Sheikh Mohamed bin Zayed Al Nahyan declared 2023 as the "Year of Sustainability". The UAE's sustainability ideals and the heritage of its founder, Sheikh Zayed bin Sultan Al Nahyan, will be reflected in the "Year of Sustainability" projects, activities, and events. This aligns with the national commitment to sustainable practices [44]. The nation will host the 28th session of the Conference of Parties (COP 28) to the UNFCCC [45]. COP28 is especially notable since it represents the conclusion of the first Global Stocktake, which started during COP26 in Glasgow [46]. Stocktaking is a two-year procedure that takes place every five years.

It evaluates the collective progress achieved by the countries and stakeholders under the Paris Agreement and suggests further action and support areas. The UAE's selection as the COP28 host underlines the government's efforts to convert the economy into one powered by clean and renewable energy sources, technology advances, and climate-smart solutions. The conference's primary theme will be the economic argument for inclusive climate action [45].

The UAE has numerous federal and municipal programs establishing clear objectives for the nation to move toward sustainable development. Several sustainable development targets have been defined in the UAE and are a guiding concept for most planned initiatives. These UAE sustainability programs include, among others, the UAE Vision 2021, the UAE Centennial 2071, and the UAE Energy Strategy 2050, which establish a 50% objective for renewable energy in the nation along with urban development. Some significant policies on sustainable environment and infrastructure are listed in Table 1.

Table 1. Sustainability policies in the UAE.

National Policy or Initiative for Sustainable Environment and Infrastructure	Objective and Strategy
UAE Strategy 2008–2010 [47]	Focus on economic diversification, education improvement, and sustainable development, laying the foundation for future research and development initiatives.
UAE Strategy 2011–2013 [48]	Prioritize cohesive society, quality education, healthcare excellence, knowledge-based economy, just judiciary, sustainable environment, and global prominence.
UAE Vision 2021 and National Agenda [33]	Built upon four pillars: national excellence, united union, competitive economy, and sustainable living. Goals encompass air quality, water conservation, clean energy, and eco-friendly growth with clear metrics.
We the UAE 2031 vision [49]	Build a diversified, knowledge-driven economy, fostering innovation, education, sustainability, and global leadership, enhancing the nation's prosperity and well-being.
The National Innovation Strategy [50]	The strategy targets renewables, tech, transport, education, health, water, and space. Execution includes decentralized power generation and innovative water scarcity solutions.
UN Sustainable Development Goals [36]	The UAE established a committee to implement the U.N.'s 17 SDGs, including initiatives like the Air Quality Index and data reporting, monitoring, and awareness strategies.
National Sustainable Production and Consumption Plan (2019–2030) [51]	Support the transition to a circular economy for sustainable resource management, endorsing eco-friendly production and consumption practices, meeting human needs while minimizing environmental impact.
UAE Energy Strategy 2050 [52]	Reduce the carbon footprint of power generation by 70% and increase clean energy to 50% of the total mix by 2050. Targeted energy mix from clean energy sources: 44% clean energy, 38% gas, 12% clean coal, and 6% nuclear.
UAE Net Zero 2050 [34]	To curb GHG emissions and limit global warming to 1.5 °C, the goal is to boost clean energy production capacity to 14 G.W. by 2030, including solar and nuclear power.
UAE Hydrogen Leadership Roadmap [43]	The Hydrogen Leadership Roadmap seeks value via low-carbon hydrogen exports, targeting a 25% market share in key import markets by 2030. Multiple projects are in progress, including A'ziz–Ruwais Chemical Hub, Masdar Demonstration Plant, UAE Hydrogen Hub, Mohammed bin Rashid Al Maktoum Solar Park, Abu Dhabi, Khalifa Industrial Zone, TAQA and Abu Dhabi Ports, and TAQA and Emirates Steel.

Table 1. Cont.

National Policy or Initiative for Sustainable Environment and Infrastructure	Objective and Strategy
National Climate Change Plan of the UAE 2017–2050 [53]	The plan balances GHG reduction and economic growth using innovation, green finance, awareness, governance, and international collaboration.
UAE Green Agenda 2030 [37]	Green Life, Clean Energy, Sustainable Environment, Social Development, and a Competitive Knowledge Economy are pillars. Programs include innovation, diversification, infrastructure, talent, and data initiatives.
UAE Circular Economy Policy [54]	Strategic initiatives in transportation, manufacturing, and food focus on low-carbon vehicles, public transit, sustainable urban design, architecture, and infrastructure, along with reuse and remanufacturing models.
The United Arab Emirates General Environmental Policy [55]	Policy targets climate resilience and supports economic priorities through nature preservation, clean air, local resource use, and waste management.
UAE Centennial 2071 [56]	Foster education, diversified economy, tech advancement, and cohesive society, reducing oil dependence, embracing innovation, and enhancing culture for long-term progress.
National Strategy for Advanced Innovation [57]	The updated strategy builds a national innovation platform, inspires community initiatives, tests novel governance, fosters new sectors, and seeks global collaboration.
Future Foresight Strategy [58]	Future Foresight Strategy aligns policies, develops future models, conducts research, builds capacities, and fosters international partnerships for sustainable progress.
Green Dashboard and KPI [59]	The UAE's Green Economy Indicators Framework includes 41 KPIs aligned with the Green Agenda's strategic objectives, managed by a dedicated committee.
Green Building Certification and Regulations [60]	Adopted international certification standards—LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method). Abu Dhabi Developed the Estidama Pearl Rating, Dubai created the Al Sa'fat Rating System, and the Emirate of Ras Al-Khaimah made Barjeel green building regulations.
Regional Policies: In addition to the national-level policies and visions for sustainable development, each Emirate in the country developed its policies and visions under the framework put forth by the central ministries to have a clear roadmap for the development of the regions. Some of the local guidelines for urban development, green agendas, sustainable infrastructure, and waste management policies are:	
Abu Dhabi Industrial Strategy [61]	Focuses on the circular economy, Industry 4.0, talent development, ecosystem enablement, home-grown supply chains, and value chain development.
Plan Abu Dhabi 2030 [62]	Focuses on the environment, land use, transportation, open space and image of the capital city.
Environment Vision 2030 (Abu Dhabi) [63]	Prioritizes climate change mitigation, clean air, water resource efficiency, biodiversity preservation, and optimized waste management for a sustainable and healthy environment.
Dubai Strategic Plan 2015 [64]	Infrastructure, land and environment: urban planning, energy and water, transportation infrastructure, environment, and waste management.
Dubai Plan 2021 [65]	Urban environment, including natural and constructed assets; a smart and sustainable city.
Dubai Integrated Energy Strategy 2030 [66]	By 2030, the Emirate expects to produce at least 5% of its electricity from renewable energy, 12% from clean coal, and 12% from nuclear power.
Dubai Industrial Strategy 2030 [67]	Focus on aerospace, maritime, aluminum and fabricated metals, pharmaceuticals and medical equipment, food and beverages, machinery and equipment.

Table 1. Cont.

National Policy or Initiative for Sustainable Environment and Infrastructure	Objective and Strategy
Dubai 2040 Urban Master Plan [68]	Plan and develop vibrant and healthy communities, double the green and leisure areas and enhance their qualities, provide sustainable and flexible means of mobility, and enhance environmental sustainability.
Dubai Clean Energy Strategy 2050 [69]	Achieve a 75% production of its energy requirements from clean sources by 2050. Initiative to build Mohammed bin Rashid al Maktoum solar park with a capacity to produce 5000 MW by 2030.
Dubai Integrated Waste Management Strategy 2021–2041 [70]	This strategy intends to promote innovative waste management technologies, recycling, and energy conversion for sustainable environmental conservation in partnership with the private sector.
Ajman Vision 2021 [71]	Ajman’s 2021 vision intends to establish the Emirate on the road to achieving this objective by developing strategies that improve the Emirate and contribute to the UAE’s overarching objective. A happy society, green economy, distinctive government, and spirit of union are the primary focus of the vision.
Sharjah Tourism Vision 2021 [72]	The strategy focuses on tourism packages, providing innovative tourism and world-class facilities, and promoting cultural and heritage elements to attract tourists to the Emirate.
Fujairah 2040 Plan [73]	The framework plan will provide local and regional strategies for integrated sustainable development in economic, social, urban, rural, infrastructure, environmental, cultural heritage, and sustainability areas.
Umm al Quwain Vision 2021 [74]	This vision aims to develop a sustainable and diversified economy in partnership with the private sector, sustainable infrastructure, improve quality of life and attract tourism.
Ras Al-Khaimah Vision 2030 [75]	The policy focuses on improving the economy, society, and environment. The objectives are set to improve GDP by 4% per year, implement more R&D investments, ensure a happy and cohesive society, improve air quality, maintain water resources, install more than 760 MW of renewable energy, promote the diversion of 75% of waste away from landfills and improve overall energy efficiency by 10%.
Ras Al-Khaimah Energy Efficiency and Renewable Energy Strategy 2040 [76]	Goal: consume 30% less electricity and 20% less water by 2040. Nine programs focus on efficiency and renewables; five enablers include awareness, tech, and policy.

Comparison with Regional and International Countries

Among the GCC countries, the UAE stands out as an energy-rich, wealthy nation with global ambitions and a greater level of engagement with international environmental regimes along with Qatar. Also, it has demonstrated its eagerness to join global networks by employing cutting-edge environmental paradigms, and has made remarkable efforts to develop sustainable policies and frameworks for current and future generations [77,78]. Due to rapid urbanization and economic and demographic growth patterns, it is challenging to keep up with the demand for essential services in the GCC’s hot and arid climate. For instance, the need for electricity is rising and may increase even further due to climate change, while the majority of energy is used for air conditioning and desalination processes. The GCC countries strongly depend on fossil fuel revenue, the integration of global markets through the export of energy resources, and the import of technology. Due to their heavy reliance on energy-intensive industrial and refining activities, Middle Eastern countries face significant obstacles in reducing emissions in sectors that are difficult to decarbonize structurally [19,77]. In response to these local sustainability challenges, the region has planned initiatives to transform the built environment and deploy efficient technologies, such as renewables, in order to bring about ecological modernization and, at the same time,

deliver results in accordance with elements of the global sustainability agenda, such as the 2015 Paris Agreement [42,79].

Figure 4 displays the ranking of GCC countries based on the SDGs. The UAE is positioned at 79th place out of 193 countries, with a score of 69.71. Notably, the UAE exhibits superior performance in comparison to other countries within the GCC.

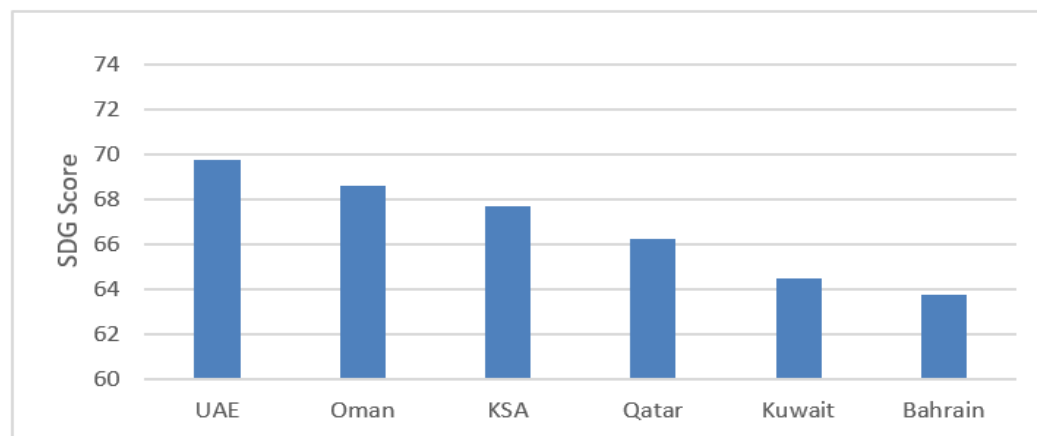


Figure 4. SDG ranking of GCC countries [29].

Over the last year, several governments in the MENA/GCC region announced net zero carbon emission targets [19,79–81]. In Bahrain’s vision, sustainability refers to economic sustainability, while environmental preservation goals are embedded in the third pillar of the citizens’ living environment. The national vision of Oman dates back to the mid-1990s and will be superseded later this year by the Oman Vision 2040. Some sustainability concerns (such as energy efficiency and environmental protection) were subsequently incorporated into the targets of the 9th Development Plan (2016–2020) under this vision. For revenue-rich countries and latecomers in terms of their respective national visions, such as Kuwait and Saudi Arabia, the emphasis is placed on diversification policies and megaprojects [82].

Nevertheless, it is imperative for the UAE to discern the specific domains that necessitate enhancement. By using the tried and tested approaches employed by nations with superior SDG rankings, the UAE may effectively implement tactics aimed at augmenting its overall performance. The UAE is capable of adapting methodologies from Denmark, which is considered one of the most energy-secure and sustainable nations within the Organization of Economic Cooperation and Development (OECD). According to the 2023 SDG index, Denmark ranks at number 3 globally with a score of 85.7 (compared to the UAE’s score of 69.7) [29,83]. The nation has successfully achieved complete autonomy in its energy production and consumption by eliminating its reliance on foreign energy sources. This accomplishment holds significant implications for other countries globally, as it provides valuable insights and lessons. The country underwent a significant transformation over the course of five decades, shifting from a state of near-complete reliance on imported fuels, namely oil, and coal, to its current status as a net exporter of both fuel and electricity. The nation currently holds a dominant position in the global wind energy technology export industry, accounting for approximately 33% of the market share for wind turbines [83]. Also, the UAE has the opportunity to draw valuable insights from Finland’s experience, wherein a comprehensive approach was adopted, encompassing regulatory measures, economic tools, labeling systems, and managerial practices. Finland, for example, emerged as a trailblazer in the implementation of a CO₂-based energy tax, representing a noteworthy achievement as the world’s first nation to adopt such a policy in 1990. Efforts directed toward the mitigation of emissions have exhibited significant efficacy, as seen by the notable decrease in air emissions, which currently exist at a fraction of their former magnitude. Finland holds the top ranking in the 2023 SDG index, with a score of

86.8 [29]. The observed favorable result can be ascribed, to some extent, to the enactment of several environmental laws and regulations [84].

4. Construction Waste Management (CDW) in the UAE

CDW is the principal waste source contributing to modern society's overall gross waste creation. The accumulation of CDW is increasing concurrently with the ongoing urbanization that is taking place all over the world [11,85]. CDW is defined as unsegregated material (other than material containing asbestos waste) that results from the demolition, erection, construction, refurbishment, or alteration of buildings other than chemical works, mineral processing works, container reconditioning works, and waste treatment facilities. It arises from the construction, replacement, repair, or alteration of infrastructure development, such as roads, tunnels, sewage, water, electricity, telecommunications, and airports, and includes materials such as bricks, concrete, paper, plastics, glass, and metal, and timber does not include excavated soil [86–88].

Waste is one of the most significant obstacles confronting the UAE building industry. Figure 5 shows the increase in CDW spanning from 2016 to 2020. One of the country's most critical businesses is unable to achieve its maximum performance due to poor planning, poor coordination between designers and contractors, and the fast-track nature of the projects. Workers' lack of awareness, poor design resulting in excessive offcuts, and rework and variations are the primary direct causes of material waste on the UAE construction sites [89]. Additionally, the shorter service life of buildings leads to early demolition and results in an increase in CDW [30]. As a result, the UAE wastes billions of dollars annually on poorly executed projects [89]. CDW is generated in every stage of construction—design, procurement, handling of materials, and operation [32,90,91]. Construction waste is the cause of increased pollutant emissions and a rise in global warming [36,92]. One of the leading waste minimization drivers in the construction industry is legislation, which includes governmental decrees and laws, organizations' policies, and contractual terms and conditions, and it plays a vital role in CDW management [32].

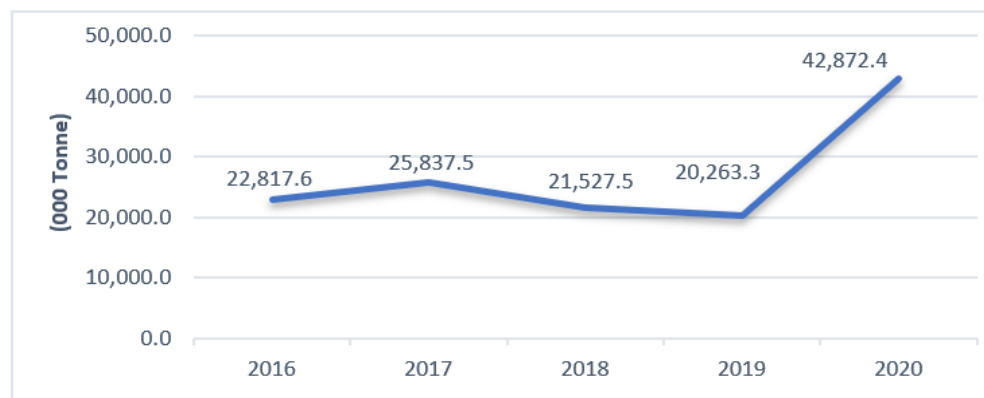


Figure 5. Construction and demolition waste in the UAE [93].

The UAE is placing considerable effort to divert 75 percent of solid waste from landfills by 2021 as part of its sustainability initiatives and policies to align itself with the growing global interest in improving waste management [34]. Federal Law No. 24 of 1999, enacted by the Government of the UAE, serves as the principal legislation governing environmental protection and regulations pertaining to the conservation and management of natural resources in the UAE. The objective of these regulations is to develop a set of guidelines related to the proper management, treatment, and disposal of waste products. The legislation aims to promote the ideas of recycling, waste reduction, and pollution control in order to protect the environment and foster sustainable development practices across the country [94]. This legislation was succeeded by Federal Law No. 12 of 2018 for Inte-

grated Waste Management, which aims to establish a comprehensive framework for waste management. This legislation consists of 35 articles that seek to implement a systematic approach to waste management and promote the use of standardized tools for proper disposal. The law also emphasizes the adoption of effective and advanced procedures and methodologies in order to enhance waste management practices. The legal framework comprehensively incorporates all facets of waste management, including but not limited to production, sorting, transportation, storage, recycling, treatment, and disposal. It also mandates the Competent Authority to manage CDW in accordance with the standards of source separation, not to combine them with other waste, and to transport them to the closest waste management facility for recycling [95].

To improve the recycling rate, the Ministry of Climate Change and Environment issued Ministerial Resolution No. 21 in February 2019, which mandates the use of recycled aggregates from CDW in road construction and other infrastructure projects for both public and private sectors in the UAE [96]. In 2018, the UAE launched the National Waste Management Database, connecting waste management authorities across all Emirates. However, various Emirates of the UAE have their own local authorities that are responsible for overseeing the various waste management tasks [97]. Municipal agencies control the country's waste management, and transporting waste across the UAE requires a no-objection certification (NOC) and limits on some kinds of waste [95]. The legislation, together with the technologically advanced CDW recycling centers, has a considerable increase in the recycling rate in the country. The implementation of this measure has led to a significant rise in the recycling rate across the nation, with figures increasing from 17.2% in 2019 to 71.1% in 2020. Table 2 presents data pertaining to the generation of CDW, as well as the rates of recycling and landfilling, spanning the period from 2016 to 2020 [93].

Table 2. Waste statistics in the UAE (2016–2020) [93].

Year	Recycling (000 Ton)	Landfilling (000 Ton)	Total (000 Ton)	% Contribution to Total Non-Hazardous Waste	Recycling Rate	Landfill Rate
2020	30,499.32	12,373.04	42,872.36	75.2%	71.1%	28.9%
2019	3495.42	16,765.87	20,263.32	57.8%	17.2%	82.7%
2018	3018.80	18,508.70	21,527.50	61.8%	14.0%	86.0%
2017	2969.35	22,703.11	25,837.52	66.6%	11.5%	87.9%
2016	2896.57	19,841.78	22,817.57	66.2%	12.7%	87.0%

4.1. Construction Waste Management in the Emirates

The Government of Abu Dhabi established the Center of Waste Management called Tadweer in 2008. The organization controls the waste management policy, strategy, and contractual systems [98]. Tadweer has set forth a standard operating procedure for CDW management in the Emirate of Abu Dhabi. The roles, responsibilities, technical, permitting requirements, as well as violations and fines for the three major stakeholders (waste producers (owners/contractors); CWM—Tadweer's licensed waste transporters; and CWM—Tadweer's licensed recycling/treatment facilities) inside the Emirate of Abu Dhabi in that sector are defined in the scope of the procedure. The CDW producers, waste transporters, and CDW recycling/treatment facilities are monitored to prevent the illegal dumping of CDW based on the UAE Federal Law [98]. Waste producers are classified either as Group A or B based on contractors involved in constructing or demolishing projects with a gross floor area less than or greater than 20,000 m². The CDW treatment, storage, or disposal facility handles shipments from a waste generator's facility property to Tadweer-approved waste transporters, developers, or organizations working on building and demolition projects in Abu Dhabi [99]. The Environmental Agency of Abu Dhabi has established specific requirements for the admission of CDW materials at these facilities.

Ready-mix concrete, curbstone concrete, demolished concrete, cement brick, precast scrap, asphalt pavements, base course layers with asphalt, and aggregate construction waste mixed with 30% fine sand and rock (small or crushed) are accepted into the recycling facility. Gypsum material or material containing gypsum is not accepted at the CDW plant. Material not mentioned above should be segregated and sent to landfill or other recycling facilities [99,100].

In 2012, the Dubai Municipality's Waste Management Department created the Dubai Integrated Waste Management Master Plan to eliminate landfill waste in 20 years using an integrated and creative strategy. In line with the plan, the Dubai Municipality is constructing a solid waste-to-energy plant for AED 2 billion. The action also supports the National Agenda to decrease waste disposal in landfills and safeguard the environment from landfill methane [70,101]. The Dubai Municipality has set forth technical guidelines for waste management in the Dubai Emirate based on the federal laws of waste management of the UAE [87,102]. In the Emirate of Dubai, the waste generator should request a permit for waste processing/recycling from the Dubai Municipality with photos of waste materials. The approval of the permit for the disposal/destruction of unwanted materials through the recycler will be notified by the Waste Disposal Service (WDS) system through email. It should be followed by requesting the WDS for permission to access a DM-accredited recycler to arrange for transportation and acquire a collection receipt and destruction certificate from the recycler for documentation [102,103].

The Emirate of Sharjah follows federal regulations and laws on waste management, and it is conducted through public-private collaboration [104]. In 2007, Bee'ah was established as a public-private collaboration by the Emirate of Sharjah for municipal waste management. Bee'ah redirects the UAE's massive construction waste from landfills. It converts 500,000 tons of highly polluted building and demolition debris yearly into industry-certified recyclable goods such as curb stones, interlocks, and recovered aggregate, utilized as road foundations or sub-bases. Bee'ah established a state-of-the-art garbage processing and recycling center to achieve this objective. For the transportation of waste and waste collection, the waste generators must request a permit from the municipality, with details of the waste generated at the site and the waste's weight. Upon approval, the waste is transported to landfills or recycling facilities [105,106].

The Ras Al-Khaimah Waste Management Agency (RAKWMA) is responsible for the management, coordination, collection, processing, and disposal of both hazardous and non-hazardous waste throughout the emirate of Ras Al-Khaimah [107]. The construction waste management follows the guidelines of Green Building Regulation Barjeel in Ras Al-Khaimah. Based on these guidelines, at least 25% of the CDW must be recycled or reused. It has mandated the source segregation of CDW in all large construction sites, in line with waste segregation requirements. The construction waste, such as clean construction waste (concrete, excavated soil, and grouting mixes), mixed recyclables (plastic, cardboard, and paper), mixed construction waste (contaminated plastic, rubber, foam, and carpets), metal, wood, and hazardous waste are to be segregated at the source by the waste generators to facilitate recycling [108]. In addition, all entities and operations within the Ras Al-Khaimah Economic Zone are required by law to comply with the legislation governing waste disposal [109]. The waste generator in the free zone should follow the waste hierarchy starting with prevention, reuse, recycling, recovery, and disposal [107,110].

Municipal administrations coordinate Ajman's waste management. Ajman continually attempts to implement critical initiatives and programs that positively impact all parts of life to support national efforts. This includes recycling, waste conversion to energy and resources, and the use of innovative technology for enhanced waste separation and collection systems, etc., to address waste challenges. The Ajman Municipality and Planning Department has begun waste management strategies and initiatives, including converting trash to energy, treating wastewater, and controlling the flow of hazardous material [111,112]. The respective municipalities handle CDW management in Umm al Quwain and Fujairah in collaboration with private recycling companies. The construction companies require

permits from the municipality for waste transportation and need to pay the disposal fee for landfill disposal through the Municipality website. This study could not find detailed waste management and recycling procedures in these Emirates due to a lack of publicly available information on waste management.

4.2. Comparison with Regional and International Countries

The UAE exhibits superior performance in recycling practices when compared to other GCC countries. However, per capita, the GCC consistently ranks among the top 10% waste-producing nations worldwide [2,113]. Approximately 120 million tons of waste are produced annually in the GCC, with 55% being CDW, 20% being municipal solid waste (MSW), 18% being industrial waste, and 7% being hazardous refuse [114]. The economic growth, lack of sustainability awareness of stakeholders, and lack of research and development in waste management have led to the rise in CDW in the GCC region. The insufficient availability of data regarding the overall quantity and management practices of CDW in the KSA hinders the capacity to make well-informed judgments by stakeholders [114]. However, KSA aims to increase its recycling rate to 40% as part of its vision for 2030. Qatar, despite its limited geographical and demographic dimensions in a global context, has a relatively low aggregate waste creation in comparison to the majority of nations. Nevertheless, upon closer examination of CDW production on a per capita basis, Qatar demonstrates one of the highest rates of waste output globally [115,116]. In Qatar, construction waste constitutes over 75% of the total volume of solid waste, with a significant portion being disposed of in landfills in the desert vicinity of the capital city, Doha. This practice has resulted in the contamination of a progressively expanding geographical area [117]. Kuwait produced around 12 million tons of construction waste in 2020, and 60–85% of the CDW waste is disposed of in landfills. The enforcement of legislation is required for better CDW management [118]. Nevertheless, it is imperative for the nation to establish a more comprehensive framework to effectively mitigate the development of CDW.

The construction sector is one of the most significant contributors to global waste production. As urbanization and development continue, CDW accumulates rapidly, placing pressure on waste management systems in both developed and developing nations. Annually, construction and demolition activities in the European Union (E.U.) generate 850 million tons of CDW. The Waste Framework Directive (WFD) established a recovery goal of 70% in CDW recycling [119]. The USA, however, introduced a policy that holds individual developers accountable for waste management and a reward for zero waste generation. The design for the deconstruction approach also helps tackle CDW in the USA [120]. In 1996, the United Kingdom implemented an increasing landfill levy, which subsequently led to a downward trajectory in the overall diversion of garbage to landfills up to the present time [121]. Following the adoption of its landfill ordinance in 2009, Germany saw a similar trend, although this type of progressive levy needs to be strictly enforced to avoid unintentionally encouraging unlawful dumping. Due to specific features in the Landfill Ordinance (progressive taxes and a landfill ban) that increased landfilling rates beyond what stakeholders could afford, it is believed that several hundred thousand tons of garbage were illegally buried in German landfills [122]. Similarly, in Spain, the legislation has indicated that all construction-related entities are required to adhere to protocols and enforce necessary measures in order to minimize the generation of CDW and ensure its proper management [123].

The UAE, like other countries worldwide, should strive to reduce the generation of CDW through various measures. These measures include raising awareness about waste management among stakeholders, implementing and enforcing waste management regulations and systems, enhancing sustainable building technologies, and allocating resources to research and development in the field of waste management [118,124].

5. Green Building Regulation for Sustainable Construction in the UAE

According to the World Green Building Council, green building is characterized by its objective to minimize or eliminate adverse effects on the environment across the whole life cycle of a structure while simultaneously generating beneficial impacts on the climate and environment [125]. According to the United States Environmental Protection Agency (EPA), green building refers to the implementation of environmentally responsible and resource-efficient practices throughout the entire life cycle of a building, encompassing various stages such as siting, design, construction, operation, maintenance, renovation, and deconstruction [126]. The global increase in energy consumption and GHGs can be attributed to the processes of urbanization, population growth, and economic advancement. Consequently, both national and international organizations are currently undertaking initiatives aimed at enhancing energy demand management, mitigating energy wastage, and transitioning buildings into generators of renewable energy [127].

Rising buildings and construction industry emissions highlight the urgent need to aggressively cut energy consumption in the built environment, decarbonize the power sector, and deploy material options that minimize lifetime carbon emissions to mitigate climate change and contribute considerably to the objectives of the Paris Agreement. Sustainable green buildings can dramatically improve the natural environment, economy, health, and equality. Sustainable green buildings and infrastructure can address climate action, health and wellness, resources, and circularity throughout their existence [128]. Green building certification and other sustainable certifications for low-emission and energy-efficient structures are essential to establishing a low-carbon building stock. Nevertheless, they must be founded on standard criteria and supported by progressive policies and mandated building rules [3]. Green or sustainable building certifications help developers and owners differentiate their facilities, demonstrate their commitment to sustainable building design and maintenance, and ensure quality throughout design, construction, and operation. LEED by the US Green Building Council and BREEAM, designed by the UK-based Building Research Establishment, are among the internationally recognized green building rating systems that measure the environmental performance of buildings. In the BREEAM system, the issuance of the certificate occurs twice during the project's progression and once upon its completion. Conversely, the LEED method simply grants the certificate with the completion of the project [129,130]. LEED and BREEAM are widely acknowledged as the most internationally recognized certifications in the field of building construction. Since 2006, there has been a growing trend in the adoption of worldwide green building standards. This may be observed by the recognition of the first project in the UAE to receive the LEED certification.

The UAE's hot climate and lower electricity prices are driving a significant surge in power consumption and CO₂ emissions, largely attributable to the heightened demand for cooling and decreased energy efficiency. As a result, in recent decades, there has been a substantial increase in installed capacity, energy demand, and yearly power consumption [23]. Figure 6 shows electricity consumption in the UAE in various sectors in 2020 [131]. In this context of increasing energy demand, the UAE building authorities and energy code agencies have tightened relevant building designs and regulations to reduce CO₂ emissions [23]. The UAE has implemented international green building certifications to raise the sustainability standards for new structures since 2006. Emirates Green Building Council (Emirates GBC) was established to highlight the extraordinary initiative taken by the UAE government to advance environmental conservation. It became a World Green Building Council member in 2006 [21,132]. In the year 2010, the UAE Cabinet authorized the nationwide implementation of Sustainable and Green Building standards. At the beginning of 2011, these requirements were implemented in government structures [37]. The implementation of the Dubai Green Building Regulations and Specifications (GBRS) in 2010 initially required compliance only for new government buildings. However, in 2014, the regulations were extended to encompass all buildings within Dubai [133].

The primary objective of the GBRS is to align with Dubai's Strategic Plan, thereby fostering a sustainable urban environment and enhancing the capacity of the Emirate's

infrastructure to cater to its forthcoming developmental requirements. In 2017, the Dubai Municipality introduced a revamped set of regulations known as Al Sa'fat, the Dubai Green Building Evaluation System, aimed at enhancing the energy efficiency and sustainability of buildings. Al Sa'fat encompasses a comprehensive set of 33 mandatory general requirements, along with numerous optional provisions that play a crucial role in determining the building's rating. These criteria encompass various aspects, such as the building envelope, air-conditioning systems, ventilation systems, and the integration of renewable energy sources within buildings [134].

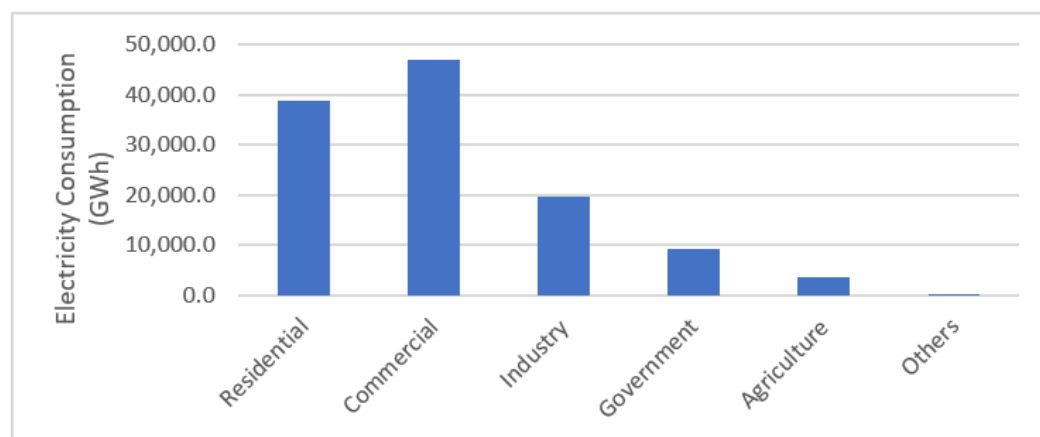


Figure 6. Electricity consumption in various sectors in the UAE [131].

In 2008, the Abu Dhabi Urban Planning Council introduced the Estidama—Green Buildings Regulations, followed by the Estidama Pearl Rating System two years later [132]. The sustainable building rating system encompasses four key pillars: environmental, economic, social, and cultural. The rating system comprises five distinct levels. Buildings that successfully adhere to all the obligatory prerequisites are awarded the Level 1 Pearl certification. Commencing from September 2010, it is mandatory for all newly constructed buildings to adhere to the 1-Pearl standard. Additionally, any buildings that receive government funding are required to attain a minimum rating of 2-Pearl [135].

In 2018, the Ras Al-Khaimah (RAK) government introduced the Barjeel—Green Building Regulations as a key component of the RAK Energy Efficiency and Renewable Energy Strategy 2040. This initiative aligns with the Government's commitment to promoting energy and water conservation, aiming to achieve significant savings in both resources. Barjeel effectively oversees the regulation of all newly constructed buildings within the Emirate of RAK, encompassing both the economic and free zones. Barjeel establishes minimum requirements for various building types in order to optimize energy efficiency and performance. The regulations specifically focus on five key areas, with a particular emphasis on energy utilization and extraction. These areas encompass energy efficiency and the adoption of renewable energy sources. In the initial year of operation, the company's compliance was undertaken on a voluntary basis. Starting from January 2020, it has become mandatory for all new construction projects to comply with its requirements [108].

In 2008, Dubai's Department of Planning and Development's division, Trakhees, which serves the lands, complexes, and areas owned by the Ports, Customs, and Free Zone Corporation, Dubai World, or any of their entities and subsidiaries in the Emirate of Dubai, implemented Trakhees Green Building Rules to improve the buildings' energy and water consumption while minimizing construction and building waste. It adheres to efforts to limit carbon dioxide emissions, ensures the use of eco-friendly materials, and implements regulations to improve indoor air quality [136].

The Green Building Regulations intend to assist the ambition of the UAE to develop more environmentally and socially responsible homes, neighborhoods, and cities to meet the needs of both the current and future generations. The UAE has also introduced building

retrofitting to existing buildings to reduce embodied carbon. The Emirates Green Building Council (GBC) launched its Building Retrofit Training (BRT) Program in August 2017 to assist in expanding the retrofit sector in the UAE. The Advanced-Level BRT Program was introduced in October 2018 to educate industry experts on retrofit techniques to assist existing retrofit projects and streamline their technical capabilities for more efficient post-retrofit maintenance and preventative care [137,138]. Existing buildings comprise most of the built environment and consume significant energy, mainly heating and cooling. Therefore, it is crucial to implement energy conservation retrofits to reduce energy consumption and the cost of heating, cooling, and lighting buildings. Existing building retrofitting guarantees a longer life with decreased operating and lifecycle costs, contributing to achieving the crucial national and global goals of eliminating carbon emissions by 2050 [139].

Comparison with Regional and International Countries

The GCC nations struggle with a distinct mix of energy and environmental issues, chief among them is the enormous need for energy. In terms of energy consumption, the GCC nations rank among the highest in the world [19]. In 1983, Kuwait implemented its first Energy Conservation Code of Practice, which has since been regularly revised to ensure its effectiveness. The KSA initiated the implementation of an energy efficiency program in buildings in 2010, aiming to optimize energy consumption and enhance overall efficiency. In 2018, the esteemed Saudi Building Code National Committee took a significant step forward by introducing the Saudi energy conservation codes, namely SBC-601 and SBC-602, specifically designed to regulate energy consumption in both residential and non-residential buildings [81]. Furthermore, it is worth noting that the Ministry of Housing of the Kingdom of Saudi Arabia has made significant strides in promoting sustainability within the residential sector through the development of the Mostadam Rating System. This system has been specifically designed to enhance the long-term sustainability of residential units, thereby aligning with the broader goals of energy efficiency and environmental conservation [81,140]. In the year 2018, the Kingdom of Bahrain made a significant stride toward energy conservation by introducing its inaugural energy conservation code. This code primarily targeted governmental entities, aiming to enhance their energy efficiency practices. By implementing these regulations, Bahrain seeks to further promote energy efficiency and sustainable construction practices across its built environment. In 2019, Qatar successfully introduced the Global Sustainability Assessment System (GSAS), a pioneering framework that evaluates and measures sustainability across various sectors [82].

Figure 7 depicts the current registration state of LEED projects in the GCC countries as of August 2023, including both completed and ongoing projects. Additionally, it provides an overview of the certification status of LEED projects that have successfully obtained LEED certification. The UAE had the largest quantity of LEED-registered projects, with 2275 projects. Following this, Saudi Arabia has a total of 1816 registered projects under the LEED certification. The number of LEED-registered projects in Qatar and the other GCC nations is quite low. In relation to the nation's overall dimensions, it is evident that the UAE, despite its relatively modest size, boasts the highest quantity of LEED-recognized projects. The potential for green projects is contingent upon the proactive initiatives and policies implemented by the government, as well as the market demand for such endeavors. In contrast, the KSA has achieved a success rate of 64% (1162 out of 1816) in terms of obtaining LEED certification in relation to the number of LEED project registrations. The observed outcome exhibits a substantial increase compared to other GCC nations. The success of a LEED project is contingent upon thorough planning and careful thought throughout the first phases. In this regard, it can be inferred that LEED projects in the KSA have been rather well administered [81,140].

In Eastern countries, such as Japan and China, the government is responsible for formulating pertinent standards and implementing them progressively. They even employ compulsory methods to ensure stringent management starting from the planning and design phase of structures. Western countries, like the United States, deviate from this

paradigm by implementing zoning rules at the federal, state, and local levels and utilizing construction standards established by non-governmental groups. The United Kingdom, as the pioneer in the adoption of green building certification, has made significant progress in the development of environmentally sustainable construction practices. Green Building Rating Systems are developed by countries with the aim of accommodating local circumstances and continuously revising them in real-time to address the evolving requirements of green building development. Figure 8 shows G.B. design and certification in various countries [13].

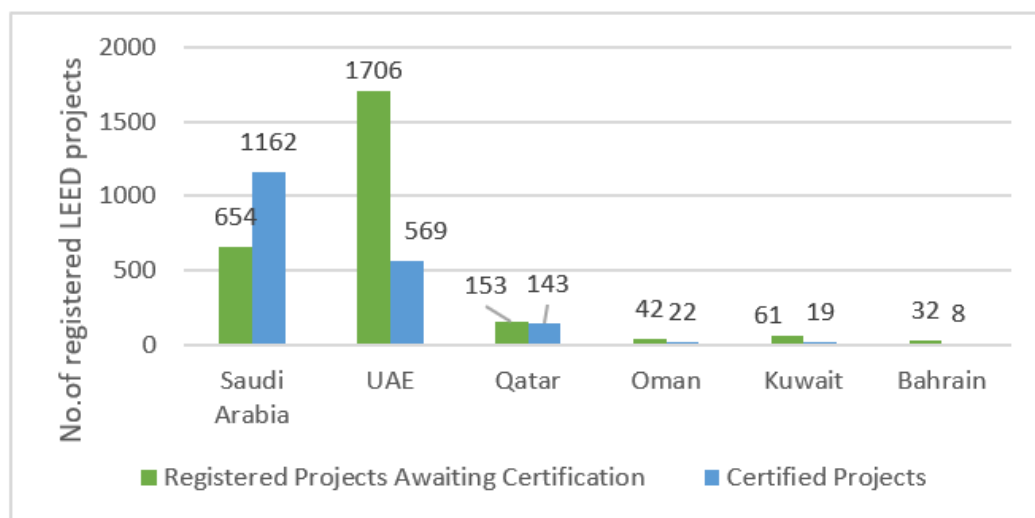


Figure 7. Number of registered LEED projects in GCC Countries [130].

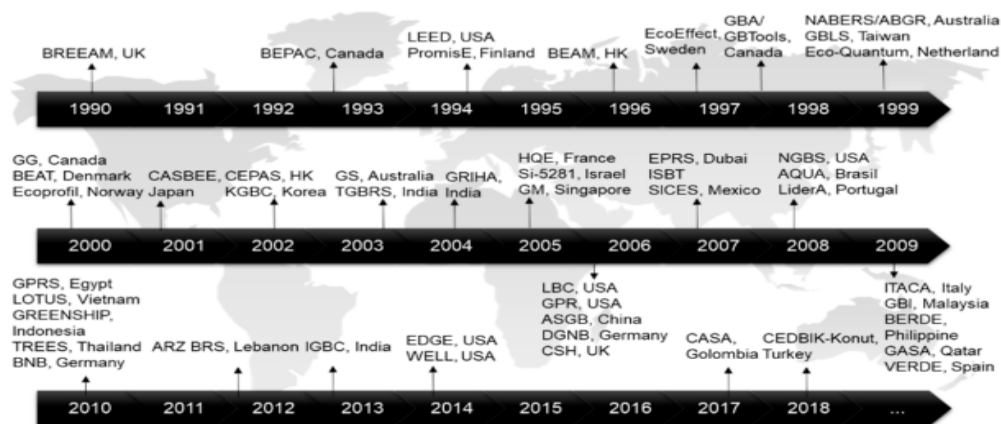


Figure 8. Timeline of green building rating system development [13].

The United States, the United Kingdom, and Japan have entered a relatively mature implementation phase for their green buildings. These nations have established and enhanced the British legal and regulatory framework. These laws, regulations, departmental codes, and regional regulations of green buildings are interdependent and mutually supportive. The faultless and comprehensive legal system provides a crucial guarantee and foundation for the standard development of the United Kingdom [128].

6. Discussions

The construction sector plays a substantial role in the UAE's economy. In recent years, the industry has witnessed a notable surge in growth, characterized by the occurrence of multiple large-scale construction projects around the nation. The UAE possesses a well-established construction industry represented by the presence of numerous international construction companies operating within its borders. Nevertheless, it is worth noting

that the building sector in the UAE makes a substantial contribution to carbon emissions. The construction sector is responsible for a significant portion of the nation's total carbon emissions due to the energy consumption associated with operating construction machinery and equipment, transporting materials and personnel, and manufacturing building materials. Furthermore, it is worth noting that CDW exerts a significant environmental impact in the UAE. The construction industry is a prominent source of waste generation in the country, and the disposal of building waste has several adverse ecological consequences.

In recent years, the concept of sustainability has emerged as a prominent topic of discourse regarding the future trajectory of the UAE. The UAE, being a participant in the Paris Agreement, has made a commitment to decrease its emissions of GHG and actively participate in the global efforts to combat climate change. The UAE endeavors to tackle the issue of climate change through a strategic emphasis on the development of alternative energy sources, as seen by the implementation of many novel programs. The UAE is currently engaged in a proactive effort to decrease its dependence on oil and adopt alternate energy sources. This encompasses investments in many renewable energy technologies, including solar, wind, biofuels, and civilian nuclear energy, with the objective of substantially mitigating the whole lifecycle of carbon dioxide emissions. The UAE government has enacted a series of laws and regulations aimed at mitigating carbon emissions originating from the construction industry and CDW.

The objective of this review study was to ascertain the UAE's endeavors in the realm of sustainable development and environmental conservation. This assessment examines various national- and Emirate-level programs that establish clear objectives aimed at fostering a more sustainable future for the nation. The UAE Green Agenda 2015–2030, the U.N. Sustainable Development Goals, the UAE Vision 2021 and Net Zero 2050, the UAE Energy Strategy 2050, the Circular Economy Policy, Hydrogen Leadership Roadmap, and the UAE Centennial 2071 are a selection of policies that have been implemented with the objective of enhancing the well-being of both current and future generations.

In conjunction with national-level policies, the seven Emirates of the country have implemented policies aimed at enhancing their infrastructure and implementing measures to improve the environment and economy. These initiatives are carried out within the framework of federal legislation and national policies. Several strategic initiatives have been implemented in the UAE to advance the goals of the National Agenda. These include the Dubai Urban Plan 2040, Abu Dhabi Vision 2030, Ras Al-Khaimah Vision 2040, Fujairah 2040 Plan, Ajman Vision 2021, Sharjah Vision 2021, and Umm al Quwain Vision 2021. These initiatives operate at the Emirates level and aim to expedite the achievement of the country's national objectives. When comparing the performance of the UAE with that of the GCC, it becomes evident that the UAE exhibits superior performance in achieving the SDGs. However, the UAE still has a considerable distance to cover in addressing the significant challenges posed by CO₂ emissions. In order to make progress, the UAE should draw insights from nations such as Denmark and Finland, which have managed to achieve lower emissions levels.

The research findings indicate that CDW is the primary contributor to waste generation inside the nation, resulting in significant adverse impacts on the environment. The literature suggests that legislation plays a vital role in waste minimization and management. Specific programs have demonstrated significant efficacy, such as the implementation of federal regulations pertaining to the utilization of recycled materials in road building. Additionally, the enactment of Federal Law 12 of 2018, which focuses on integrated waste management, has resulted in the diversion of 70% of CDW away from landfills. The implementation of CDW management practices, adherence to legislation, and establishment of waste-to-energy plants have positioned the country as a leading contender in the pursuit of an improved and more environmentally sustainable trajectory. CDW is a prevalent issue both within the GCC region and on a global scale. Governments are actively striving to enhance recycling efforts, implement landfill levies, and embrace construction methods that aim to decrease waste generation.

The implementation of green building standards, certifications, and retrofitting practices in the UAE provides developers with a means to distinguish their facilities and showcase their dedication to sustainable building design and management. Certifications assess the degree to which a building conforms to international standards and relevant rules. The UAE adheres to many sustainable building standards, including the Estidama Pearl Rating System, the Al Sa'fat Green Building policies, and the Barjeel and Trakhees Green Building Regulations. These policies are complemented by globally renowned certifications such as LEED and BREEAM. The UAE and the KSA have a higher number of registered LEED projects, with the KSA taking the lead in terms of certification. The study also aimed to provide insight into the various green building certifications that are currently in place worldwide.

7. Conclusions and Future Work

The UAE is widely regarded as a highly desirable tourist destination globally, mostly attributable to its impressive megastructures and the substantial investment of over USD 710 billion in ongoing construction projects aimed at fostering economic growth and development. Despite the UAE government implementing several objectives for sustainable development, there is a lack of supporting legislation and rules to effectively regulate CDW generation on building sites. The nation will require additional initiatives in order to effectively address the issue of CDW. The legislation in the UAE might benefit from an increased emphasis on the establishment of benchmarking mechanisms for performance evaluation and the implementation of a standardized national framework for data gathering within the construction industry. A legislation of this nature may encompass a comprehensive structure aimed at addressing the key stakeholders involved in the sector, with a specific focus on waste reduction throughout various stages of construction, including design, planning, operation, maintenance, and decommissioning. The relevant governmental entities should conduct an analysis of these statistics in order to facilitate monitoring, documentation, and benchmarking objectives.

The implementation of incentives and reward programs has the potential to foster a greater emphasis on sustainability among construction stakeholders. The review revealed that, in general, contractors in the construction sector are incentivized to prioritize fast and cost-effective construction rather than prioritizing the minimization of environmental impact during the development process. Hence, it is imperative that Key Performance Indicators (KPIs) within the construction industry encompass sustainability as a fundamental element, alongside considerations of cost, schedule, quality, and safety. This assessment also highlighted the necessity for an increased stakeholder understanding regarding the significance of sustainability in construction activities, as well as the presence of inadequate communication among team members, leading to a heightened waste generation during the project development phase.

Further investigation should be undertaken by research institutions to explore the areas of lifetime cost analysis, value engineering in the utilization of recycled aggregates, and waste-to-energy technologies. These research endeavors aim to generate more valuable resources from waste materials. Furthermore, it is imperative to conduct research on implementing green building laws in all construction projects throughout the UAE, with particular emphasis on the private sector. Additionally, it is recommended to promote retrofitting programs for existing structures as a preferable alternative to demolition. The UAE government is unequivocally committed to attaining its sustainable development goals. The UAE has undertaken many measures, including the implementation of 'the Year of Sustainability' and the hosting of COP28 in 2023, with the aim of showcasing its dedication to ensuring a sustainable future in order to protect its population, natural resources, and territory. Based on the findings of this study, it is recommended that further research be conducted to develop a framework and roadmap for stakeholders in the construction sector. This framework and roadmap would aim to enhance the awareness of existing

policy and legislation, as well as strategies for fostering more remarkable contributions toward the sustainable development agenda.

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