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## Review Paper

# Sustainable eco-house for low-income earners in Dhofar region: A Review

**Marwan Ahmed B. Farhan** <sup>ID</sup>, **Aiman Bin M. Rashidr** <sup>ID</sup> and **Muhammad Faizal Bin A. R.** <sup>ID</sup>

Department of Architecture, Faculty of Built of Environment and Surveying, Universiti Teknologi, Malaysia.

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## ABSTRACT

The recent drop in oil prices has led several countries with an oil-dependent economy to consider new sustainable policies and attitudes. One of the strategies is the potential ability of the Smart-Eco home to provide a quick and effective solution to support the current national policy of promoting more sustainable practices. Efficient houses built in a way that respects resources and that last long in quality systems are said to be the way forward to achieving a low carbon footprint and a sustainable environment. These houses are constructed from high-performance, energy-saving materials with an energy-maximizing building orientation. Considering government policies are mainly geared towards constructing houses, if sustainable, they would not only be affordable for a few populations but also for the low-income earners. Therefore, this review aims to expound on the importance of eco-housing in achieving sustainable housing for society. The paper aims to draw the attention of the government, experts, decision makers, and educational institutions to integrate the smart eco-house into their efforts towards efficient energy performance buildings, supporting the national economy, the energy infrastructure, and part of the country's environmentally sustainable policies.

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## 1. Introduction

In recent decades, global awareness of environmental issues and the desire for sustainability have become increasingly popular [1]. Accordingly, the world realized that sustainable and green eco-friendly architecture is the ideal model to be adopted to sustain the economy and environment. By embarking on sustainable architecture, a considerable amount of money spent on energy and water is saved, natural resources are conserved, pollution is reduced, and decreased reliance on the infrastructure frees up money and resources to be spent on people's quality of life [2]. Worldwide, there has been a large-scale proliferation in the construction of houses due to population growth, economic development, urbanization, and migration, which has in turn had a ripple effect on sustainability [3]. According to the National strategy for ecologically sustainable development, sustainability is referred to as the development that improves the total quality of life. The daily lives of people, their health, security, and well-being are affected and influenced by the locations of their homes, their construction and design, and how well they are woven into the environmental, social, cultural, and economic fabric of communities [4]. Sustainable housing development can offer opportunities to promote not only environmental conservation and economic development but also quality of life and social equality while mitigating numerous precarious problems relating to population growth, urbanization, slums, poverty, climate change, lack of access to sustainable energy, and economic uncertainty [5]. Studies have shown that five eco-houses have been developed and built on university campuses in three governorates, including Muscat the capital, and Dhofar regions of Oman [6]. Furthermore, as part of Oman Vision 2020, the government has invested in mega-scale infrastructure projects that use green building materials and sustainable construction practices [7]. Sustainable housing development could be successfully achieved if an optimal balance is ensured between sustainable housing and residents' satisfaction [8]. The sustainable smart eco-houses should be environmentally safe, socially inclusive, and economically productive [9].

The signing of the Paris Agreement of 2015 to achieve no net carbon emissions is a step towards sustainability [10]. Furthermore, the Research Council has started to disseminate the concept of green and sustainable architecture through the introduction of sustainability to educational curricula and announcing a contest for an eco-house design among higher education institutions [11]. An effective and realistic tool to achieve the country's strategic plans for a sustainable future requires intensive efforts from the government, municipalities, lawmakers, policymakers, educational institutions, media, and others. This paper aims to propose this perspective of including the smart house as an effective tool for achieving sustainability strategies for the Dhofar region and other regional countries. In environmental terms, sustainability implies the long-term conservation of natural resources as well as the maintenance of a diverse, productive, and resilient environment. Awareness of environmental, social, and financial sustainability is required for the global establishment of eco-houses specifically for low-income earners in the Dhofar region. Given the relationship between carbon emissions, global warming, and natural disasters, the need to integrate environmental considerations and concerns into all aspects of economic and social decision-making, and the growing awareness of the financial and non-financial costs of depletion and degradation of natural resources becomes necessary. This study attempts to highlight the significance of eco-friendly houses for low-income earners with a focus on the Dhofar region and prevent global warming by constructing eco-friendly houses. This review will guide readers through examples and case studies derived from sustainable urban design projects that have been effective on a global scale. By demonstrating concrete advantages like lower energy usage, better air and water quality, and the development of inclusive, pedestrian-friendly communities, this review sheds light on the revolutionary potential of environmentally conscious building techniques. Through the consolidation of these findings, this analysis seeks to guide city planners, architects, and lawmakers toward a more profound comprehension of the complex interplay between environ-

\*Corresponding Author.

E-mail address: [ahmedfaraj@graduate.utm.my](mailto:ahmedfaraj@graduate.utm.my); Tel: (+968 232-37337) (Marwan Farhan)



mentally conscious construction methods, prosperous urban communities, and sustainable urban design.

## 2. Sustainable Architecture

Sustainable architecture refers to designs that aim to improve the limit on environmental impact while achieving efficiency and positive impacts on the health of the inhabitants. It also involves research on natural resources that are completely reusable [12]. Researchers have suggested that sustainable architecture should show ecological awareness and a relationship between its appearance and functionality [13]. Zhong et al. [14] revealed that a green building that is designed and constructed using processes and resources that do not compromise the health of the environment, as well as the building's occupants, workers, public, and future generations, can be described as sustainable architecture. While sustainable design aims to minimize the ecological footprint caused by human activities, sustainable architecture emphasizes utilizing eco-friendly energy sources and implementing efficient water management practices [15]. Negi et al. [16] demonstrated that such sustainable objectives are to reduce inefficient and detrimental energy usage by employing sustainable energy sources, such as solar panels, passive heating and cooling, and ventilation systems.



Figure 1. Three pillars of sustainable architecture.

Generally, sustainable design integrates renewable and environmentally beneficial resources, including bamboo, hemp, cork, flax, soy, recycled and upcycled materials, and eco-friendly insulation. Ragheb et al. [17] reported that by utilizing flexible, modular areas, several sustainable architectures constructed from organic materials can be readily disassembled and used or recycled. It was explained that recycled shipping containers can be used to create sustainable dwellings and apartment buildings, offering alternative housing choices [18]. Detailed studies by a group of researchers [19] agreed that one key feature of sustainable architecture is the integration of plants and nature using living walls, residential towers covered with trees, and roofing materials designed to promote cooling. This approach not only helps to improve the environmental sustainability of existing buildings but also creates biophilic environments that are beneficial for human health. Furthermore, Jones [20] reported that indigenous flora has a crucial function in the design of environmentally friendly buildings because they enhance local biodiversity, mitigate soil erosion, and necessitate less upkeep because of their natural adaptation to the local environment. When creating a sustainable building, the architect aims to achieve a net zero effect by ensuring that the structure generates at least the same amount of energy as it consumes. Water conservation technologies are also employed, such as rainwater collection and greywater recycling. Studies have shown that sustainable architecture has gained significant attention in addressing environmental, social, and economic challenges [21]. Currently, sustainability development encompasses three primary categories: 1- Social Sustainability, which pertains to a system's impact on society; 2- Economic Sustainability, which relates to economic associations; and 3- Environmental Sustainability, which concerns the impact on the environment. These three sustainability categories were initially proposed by Elkington in 1994 and persist to the present day. Figure 1 illustrates the three categories of sustainability. This study examines the environmental sustainability category by evaluating the effects of implementing sustainability criteria on building environmental performance. This aims to elucidate the environmental implications of construction and the methods to mitigate these effects through sustainable

building design principles [22]. Sustainable housing follows the principles of sustainable development, which include making good use of resources during construction and use, reducing negative effects on the environment, and prioritizing the health and comfort of occupants. However, globalization, shifting demographics, changing weather patterns, and the economic downturn are the main forces for sustainable housing development [23].

### 2.1 Sustainability and eco-friendly housing

Sustainability and sustainable development have firmly been established in national and international policymaking in the past 50 years. Nevertheless, there needs to be more focus on the concept of sustainability in indigenous cultures. Although sustainability is often considered a universal concept that can be applied regardless of social, political, or cultural context, it is contended that a comprehensive model of sustainability for non-indigenous societies can only be achieved by recognizing the significance of culture and integrating the wisdom accumulated over generations in indigenous knowledge systems [24]. The world is facing numerous challenges such as climate change, deforestation, depletion of fossil resources, overexploited fisheries, species extinction, and contamination of our food and water which are attributed to the unsustainability of the environment and require an eco-friendly approach. Creating an environmentally friendly home requires a comprehensive approach that considers factors such as insulation, ventilation, renewable energy sources, appliances, materials, passive design methods, and water efficiency as shown in Fig. 2. The incorporation of solar energy into eco-friendly homes exemplifies the continuously growing capacity of sustainable technology, ushering in a future where homes serve as not just living spaces but also active generators of environmentally friendly power. Amidst the global pursuit of waste reduction and increased environmental accountability, the emergence of sustainable materials serves as evidence of the profound impact that deliberate design decisions can have and can contribute to a more sustainable future, playing a role in combating climate change on an individual basis. Researchers have argued that the reason for the unsustainability is ascribed to the way the world is viewed [25]. However, the difficulty lies in transitioning from general catchphrases to precise methodologies and procedures that aid in comprehending intricacy, formulating more effective strategies, promoting individual and organizational education, and instigating the necessary technical, economic, social, political, and personal transformations to establish a sustainable environment. Furthermore, the organization of sustainability research, teaching, and engagement with the policy process can ensure the provision of scientifically rigorous and dependable knowledge that transcends disciplinary boundaries, involves various stakeholders, addresses ethical dilemmas, values, and objectives, and ultimately results in concrete sustainable action and eco-friendly structures [26].



Figure 2. Components of an environmentally friendly home.

While sustainability implies the responsibility to conserve natural resources and protect global ecosystems to support health and well-being, eco-friendly housing pertains to residential structures that are intentionally designed and built to minimize their ecological footprint [27]. Soviana et al. [28] revealed that environmentally sustainable housing can also serve as a spur for community involvement and cooperation. Another benefit of sustainable awareness is that inhabitants of environmentally conscious dwellings can exchange ideas, pool resources, and work together on sustainability projects that benefit the

entire community. Other authors have reported that eco-friendly houses are beneficial for the environment and human welfare [29]. If citizens unite in adopting eco-friendly homes as a lifestyle, there's a high likelihood that local authorities will likewise unite in formulating regulations and environmental policies. The most ideal result is that all citizens will live in a healthy environment with abundant resources. In realizing the importance of a sustainable environment, the public should be well informed and directed to understand the importance of the environment by leaving the conventional homebuilding culture. Through the knowledge gained in the awareness of the sustainable environment and the superiority of eco-friendly houses, it is expected that the public will begin to change their orientation and start using the eco-friendly concept for designing their homes. At this stage, decision-makers, and the stakeholders can provide information about the concepts and methods to build eco-friendly houses. Eco-friendly houses can function as instructional instruments in multiple ways and the eco-house utilizes a home automation and information system to encourage sustainable habits and decisions [30]. A typical eco-house shown in Fig. 3 was designed by a group of researchers [30]. With the use of a home automation and information system (HAIS), the Ekó House was created by researchers [30] to serve as both a temporary residence and an instructional tool. As a vital tool for users' awareness, the HAIS blends weather data with information about house performance and provides useful information about the connection between the systems. Another similar study showed that teaching green and sustainability at school builds frameworks that combine architecture and environmental education to involve students in sustainable living [31]. Roysen et al. [32] demonstrated that ecovillages, like the one in Brazil, offer a comprehensive approach to sustainability education that integrates various disciplines. Geth et al. revealed that open-source smart energy buildings have the potential to be utilized in K-12 education to teach about energy efficiency [33]. Despite many studies [34] performed to understand the concept of eco-housing, the overall understanding is that the primary emphasis should focus on utilizing environmentally friendly construction materials, implementing energy-efficient technologies, and advocating for waste reduction and recycling as shown in Fig. 4. By integrating environmentally conscious techniques into the design and construction of homes, contribution to the overarching objective of long-term sustainability can be achieved by minimizing the impact on the environment and conserving resources for the future. Ragheb et al. [17] encapsulated fundamental principles, tactics, and technologies that are linked to the five primary components of green building design. They reported that the key areas of focus are sustainable site design, water conservation and quality, energy and environment, indoor environmental quality, and conservation of materials and resources.



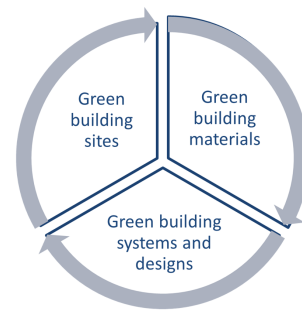
**Figure 3.** An eco-house built as a temporary residence and an instructional tool [30].

## 2.2 Sustainability in the construction industry

Traditional construction methods in the industry increase errors and waste due to rework and manual updating. Building Information Modeling (BIM) enhances efficiency and sustainability in the design phase. A case study showed that BIM and structural analysis software (Robot and Etabs) closely aligned design results, with a minor discrepancy in rebar quantity. The entire process, from modeling to analysis, design, and quantity estimation, was executed efficiently and yielded good results [35].

Although the construction sector spends a lot of money on project/construction execution, building material procurement, maintenance, and demolition, the industry however, contributes to meeting basic social and physical needs by providing infrastructure, accommodations, and consumer goods, so stimulating and generating large economic returns. In contrast, studies have shown that the industry has a negative impact on the environment in terms of land use,

water usage, resource usage such as material and timber consumption, and greenhouse gas emissions [36]. According to Opoku et al. [36], "Construction that brings about the required performance with the least unfavorable ecological impacts while encouraging economic, social, and cultural improvement at local, regional, and global levels is one approach that suggests using sustainable construction practices. As a result, the adoption of sustainable construction practices has globally been recommended [37]. According to Khalfan et al. [38], sustainable building is a process that incorporates the triple bottom line (TBL) to provide a sustainable result that includes social responsibility, environmental accountability, and economic revenues. The concept of TBL has been viewed by several authors as the construction of a building that encompasses energy savings, safeguarding occupants' health, and maintaining their well-being. Studies show that there have been several studies performed concerning the sustainability of the construction sector in terms of materials, cost, and environmental friendliness, and results are presented as shown in Table 1. While several researchers have reported that environmentally sustainable construction is mainly focused on the efficient use and management of material and natural resources, according to Alsharif et al. [39] an organization can only be considered environmentally sustainable if it strives to consume natural resources at a rate lower than the reproduction rate, emits at a rate lower than the natural system can absorb, and refrains from engaging in activities that degrade ecosystem services. In another study, Edum-Fotwe et al. [40] reported that sustainable development can include social issues combined with environmental and economic issues.



**Figure 4.** General concept of eco-housing.

## 2.3 Sustainability awareness and integration into the educational system

Raising awareness is the key to any issue or topic about the well-being of a country, place, environment, and society. It is a signal to all citizens to pay attention and participate in taking care of their surroundings [41]. Raising awareness of sustainability can unite a community or region in embracing eco-friendly homes as a lifestyle [42]. Awareness is critical in promoting a sustainable society, as public understanding is the key to instigating the changes necessary to solve issues. Saraiva et al. [43] defined sustainable awareness as a movement toward a pivotal human revolution and a culture of sustainability. The goal is to receive feedback on ongoing activities to design long-term and short-term programs aimed at promoting the environment and sustainable development. The increasing awareness of issues related to the environment and the aspiration for sustainable lifestyles have resulted in the emergence of housing projects that prioritize ecological preservation [44]. These residences exemplify community awareness by demonstrating sustainable practices and integrating environmentally friendly elements [45]. To create a sustainable society, there needs to be a conscious effort to direct actions to meet the needs of present and future generations. Awareness stimulates informed action by helping to convert general and vague desires for sustainability into clear goals. It is important to promote environmentally friendly consumer habits and lifestyles, and this often requires a shift in cultural values [46]. The common assumption is that environmental conservation contradicts economic growth and societal well-being, making the sustainability awareness task challenging [47]. By sending the right message, awareness can help dispel myths and work towards fostering a culture of sustainable development at the individual, community, and national levels. Kaisu Sammalisto et al. [48] investigated the procedural implementation of sustainability in the courses at a Swedish University. The result showed that introducing the concept of sustainability influenced and increased the overall understanding of awareness at the University. In another study, Tasdemir et al. [49] explored the feasibility of incorporating sustainability into the curriculum of higher education institutions from a transdisciplinary standpoint. The developers of the course curriculum aimed to match higher

education institutions with corporate organizations strategically. They achieved this by integrating modern management approaches and sustainability themes. The results indicated that the suggested course material effectively enhanced awareness of sustainability at both the overall and individual levels of sustainability pillars.

**Table 1.** Sustainability of the construction sector.

Objectives of study	Finding	Ref.
Investigated the role of policy and regulation in promoting green buildings.	The result demonstrated that the promotion of green structures through policy and regulation is a critical component in the pursuit of sustainable development objectives.	[50]
The paper investigated the critical success factors of sustainable education in three countries about the recovery of green energy resources.	The attitude of the learners, the prevalence of green culture in society, and the backing of government institutions concerned with the environment are, according to the findings, three critical success factors for sustainable development education.	[51]
Investigate the behaviour of corporate social responsibility in the construction sector.	The result demonstrated that cooperate social responsibility and awareness contributed to the sustainability of the construction sector.	[52]
conducted a thorough study of recent studies comparing sustainability assessment approaches.	The methods employed enhanced understanding and provided platforms to address issues related to sustainable practices in the construction sector.	[53]
The approaches used improved understanding and created platforms for discussing concerns linked to sustainable practices in the construction industry.	The article discusses green practices such as the sustainable sourcing of construction materials and the influence of policymakers on sustainability.	[54]
The research study investigated the understanding and sustainability literacy of construction professionals at both the theoretical and practical levels.	The result revealed a link between high academic awareness and low practical knowledge because of a broad interpretation of the sustainability concept.	[55]
The study proposes a service-oriented platform that incorporates access to sustainability resources to address a lack of awareness and positive energy practice.	The findings connect to the research topic by suggesting a potential solution for overcoming barriers to sustainability in the construction industry.	[56]
The article explored the usage of green construction materials like wood as a means of promoting sustainability.	The results demonstrated that stakeholders' adoption of the proposed concept varies depending on their level of sustainability education.	[57]
A study examined the influence of lean construction techniques indicated a positive effect on the TBL dimension of sustainability.	The TBL factor was addressed, and the study found that implementing sustainable practices resulted in a variety of benefits.	[58]
The study measured sustainability views of construction materials.	The result identified Sustainable construction materials to reduce the negative influence on the environment.	[59]
The study analysed the correlation between effective stakeholder engagement and the development of a thriving sustainable practice.	These factors were perceived as both a driver and a hindrance to sustainable practice, according to the findings.	[60]

A group of researchers [61] at the Group at the University of Plymouth explored and designed a sustainable building project proposal for a real-life site. The researchers employed different approaches which included site survey, design development, using CAD, and analysis efforts to underpin design decisions. The result showed that the integration of sustainability increased the student understanding and execution of the eco-house project. In a similar study by Patel et al. [62] they found that the primary barriers to the adoption of sustainable building practices include a lack of awareness, lack of cost savings, and lack of reliability. Despite several studies performed to understand the challenges and barriers to implementing sustainable housing, the overall understanding is that sustainability as a concept can be integrated into the school curriculum and

applied in different communities. Higher education is a hugely influential stage in an individual's life, the time when people begin to think critically about the world, understand their place in it, and acquire the skills to make a difference. Furthermore, researchers [63] have shown that curriculum development is the foundational building block for integrating sustainability into higher education. A successful method is starting with a course or even an entire curriculum based on sustainability itself is a successful method. As stressed by (Basiago [64], offering courses in sustainability's many facets is crucial to addressing the pressing issues of environmental, social, and economic degradation that the world currently faces. Once the courses are in place and established, the next step is to infuse sustainability content into core classes for all majors, reaching a broad spectrum of students.

## 2.4 Benefit of Eco-house in the community: A case study of the Dhofar region

The construction of eco-friendly houses has become increasingly relevant in addressing environmental problems on a global, regional, and local scale. This adoption of eco-friendly practices can lead to various benefits for the community. Koengkan et al. [65] reported that eco-friendly houses can significantly reduce their environmental impact compared to traditional houses. They showed that eco-houses can consume fewer natural resources, produce less waste, and emit fewer greenhouse gases, contributing to a more sustainable environment. In another similar study, Maury-Micolier [66] demonstrated that eco-houses can enhance indoor air quality, prioritizing the use of non-toxic building materials and ventilation systems that improve indoor air quality. It was recommended that the eco-friendly houses create a healthier living environment for residents, reducing the risk of respiratory problems and other health issues. Nevertheless, the primary obstacle encountered by developers and customers is a dearth of knowledge regarding the advantages and possibilities associated with green buildings [67]. However, one of the main concerns of people regarding eco houses is the cost, some of them believe that the cost can be high because of the solar system, which is expensive in many countries, especially Middle Eastern countries. In a study conducted by group of researchers [68,69] they discuss the development of decision-making criteria for evaluating social attitudes towards green lifestyles and eco-friendly buildings, based on a review of existing literature. The validity of the criteria was established by conducting a short pilot study among company executives and academic staff and analyzing the results. The results showed that constructing homes within a community offers various benefits and opportunities, including shared infrastructure, renewable energy systems, communal recycling facilities, a collective garden, bulk purchasing, and exchanging construction skills and advice. It was found that the community self-build approach to new housing offers a chance to develop more sustainable and low-carbon communities [70]. According to Khoukhi [71], passive design solutions can help to save the environment by emphasizing the conservation of both natural and built environment, reducing environmental damage, and minimizing the consumption of energy in the operation of buildings. Travel between essential activities, and prioritizing the adaptation and re-use of buildings, infrastructure, and roads can be some of the advantages of eco-friendly houses. It was revealed that recycled building materials, using local material components, assuming self-sufficiency at all levels of settlement structure, changing the present energy-wasting lifestyles, promoting diversity that allows a mix of different building types, and promoting closed-loop productivity through recycling and the use of alternative energy sources are essential for an eco-friendly environment through eco-housing projects [72]. The Dhofar region of Oman has an economy that is heavily reliant on non-renewable oil and people widely acknowledge the finite nature of this income source. However, when oil production peaks, it is predicted to be a rapid decrease in the availability of this resource, which spells severe economic problems for the region [73]. In recent years, the region's climate has also undergone a radical change. Dhofar has become increasingly arid, which has resulted in the decline of the region's agricultural industry. Many native plant, insect, and bird species are believed to have migrated or become extinct due to the changing climate and lack of irrigated farms. An eco-home construction industry could help offset the economic problems associated with declining oil revenues and stimulate sustainable economic growth. The Dhofar Eco House built at Dhofar University is one of five eco-friendly houses built in Oman as part of the Eco House Design Competition. The eco-house is shown in Fig. 5. The project was aimed at inspiring the community about the importance of eco-housing and sustainable architecture while taking into consideration the same traditional architectural features that are used in local houses. Interestingly, the house is currently used as a research center for students and researchers at Dhofar University and receives visits from neighboring schools and the public. According to the visitors' reviews, this is the first time they have heard about eco houses and sustainable buildings and

were exiting about the idea of the house and the benefits it offers to the owner and the environment. Therefore, this house can be used as an educational tool to raise the Dhofar society's awareness about the importance of eco-friendly housing in the future. The eco house shown in Fig. 5 is equipped with solar panels that supply power to the entire building and equipment. During the summer, eco-friendly homes remain very cool. On the contrary, during winter days, these types of homes trap heat, leaving them warm all day and night, and this is attributed to the passive solar heating and cooling features incorporated in the eco-house at Dhofar University demonstrating the importance of sustainability of eco-housing as highlighted in the section 2.2 of this study. An eco-friendly home can save energy by using efficient appliances, keeping the home well-insulated, and modifying the home's structural design. Yazyeva et al. [74] revealed that employing sustainable materials in the construction of eco-houses can provide several advantages in terms of materials, cost, and environment. By producing less heat than non-renewable energy sources, increasing users' energy savings, and providing higher-quality lighting and heating appliances, solar energy systems can provide clean, silent, and cost-efficient energy. Pandey [75] reported that the use of local materials in eco-home construction can provide significant jobs for job seekers. Embarking on eco-home construction would also create a demand for research and development of new technologies. Due to the region having very limited access to professionals with expertise in eco-home construction, this could be an opportunity to invite foreign consultants, which would stimulate knowledge transfer. An industry of this nature would also complement the widespread afforestation activities in the region and could boost other micro industries related to the environment.

## 2.5 Approaches to eco-friendly housing for low-income earners

The cost of housing relative to household income has, nevertheless, been the primary lens through which affordable housing has been perceived [76]. The capacity of households to obtain appropriate housing without incurring crippling financial burdens was also interpreted as part of the idea [77]. Furthermore, sustainable affordable housing is an environmental strategy that aims to achieve energy conservation in buildings. This is achieved through promoting and encouraging the use of energy-efficient lighting, heating, ventilation, and air conditioning systems; installing water-efficient appliances; improving the housing envelopes generally; and solar heating and electricity. The already expensive cost of housing could rise even more as a result of these measures and the problem could be mitigated through the implementation of an incentive-driven housing market [78]. Hence, the indoor and outdoor living conditions of low-income individuals will undoubtedly improve as a result of embracing eco-housing project initiatives as highlighted by Okereke et al. [78]. Bredenoord [77] revealed that one of the reasons low-income people do not have access to enough housing is because plentiful local resources are not being utilized. Furthermore, Alfahad et al. [79] demonstrated that the high cost of imported construction supplies also puts them out of reach for many low-income families. Nonetheless, sustainable affordable housing's environmental policies including promoting and employing local resources can be a strategy to support eco-housing for the low-income earners [80]. As part of its environmental strategy, sustainable affordable housing stresses the need to encourage the use of local resources by providing tax breaks and other incentives to business owners who are interested in investing in this area. Housing for low-income families will become more inexpensive because of a precipitous drop in the price of imported building materials brought about by the development and utilization of local sustainable resources in construction. It will also cause new employment opportunities to arise, thereby improving the lives of low-income earners. Among the many eco-friendly approaches to inexpensive housing, specifically for the low-income earner, one is to reduce the likelihood of natural catastrophes by conducting environmental and geological studies before construction. The assessments help identify potential hazards, both current and future, and then take measures to lessen their impact. The assessment and the project's combined costs may seem exorbitant, but the hidden value they foretell makes it all worthwhile. In a similar vein, private investors and developers can be incentivized to participate in the environmental assessments, so low-income people cannot face any additional financial burden as a result. Sustainable affordable housing practices advocate for ongoing policy reviews and updates to better meet the housing needs of low-income earners in light of current conditions. A comprehensive housing strategy should cover all bases, including land for housing, building materials, dwelling kinds, income groups, and many other issues [81]. For instance, several people believe that the delivery of housing to low-income families has been hindered for decades due to social menaces such as the pursuit of profit at the expense of qualified individuals, unreasonable professional charges, and the hiring of unqualified individuals to staff housing departments and agencies [82]. Sustainable affordable housing practices, however, can fix all of these

problems. For affordable housing to be a long-term solution, institutions and policymakers must prioritize an open and efficient procurement process as well as create sustainable awareness [83]. There should be less room for favoritism, incompetence, and excessive profiteering if the procurement process is open and efficient. This will undoubtedly facilitate the redistribution of low-income eco-housing projects from the government. A transparent and efficient procurement procedure can also result in significant cost savings and contribution to the eco-housing projects. Decentralizing planning and approval powers and duties to local authorities is a central tenet of an institutional strategy for sustainable affordable eco-housing [84]. Decentralizing and moving approvals to local authorities can save a lot of time. Furthermore, more low-income housing units and eco-housing could be built if developers are incentivized.



Figure 5. Dhofar Eco House, Dhofar University, Salalah, Oman.

## 2.6 Eco-house development and prospects

Problems with developing sustainable affordable housing in developing countries have been highlighted and they include a lack of technical expertise, an incorrect understanding of sustainable technological processes, doubts about technological performances, and the constant evolution of technology [85]. Developmental activities have led to environmental degradation and skyrocketing construction material prices, both of which highlight the urgent need to develop and enhance local resources to sustainable levels. Technology is also necessary for improving local resources to meet sustainable requirements and one important technical strategy for long-term, low-cost housing emphasizes the need to encourage innovation in this area. The approach can raise the necessary level of consciousness in addition to encouraging the use of renewable, recyclable, and reused materials. Through this technical method, sustainable cheap housing and the ecosystem can be preserved and disasters better controlled [77]. In a similar vein, the rate of technological advancement is a boon to established sustainable eco-housing and the technology strategy for sustainable affordable housing that promotes, grows, and develops local and basic technologies might help overcome many of these obstacles. The shortage of trained labor can be alleviated, and new direct jobs can be generated by encouraging the advancement and expansion of local technologies. There will be a significant reduction in the enormous costs associated with employing and bringing in experts. Consequently, lower-income individuals will have much easier access to homes because prices would be significantly decreased. Moreover, a study conducted in Iraq aims to illuminate the inaugural academic sustainable housing project developed by fourth-year students in the Architecture Engineering Department at Baghdad University in 2015, situated in a location within Baghdad selected for its environmental and site potential to achieve urban sustainability. The academic project aims to implement principles of sustainable urban neighborhoods, beginning with development and planning strategies that incorporate mixed uses, transit-oriented development (TOD), and green transportation. It emphasizes the preservation of natural areas and culminates in design practices that promote compact, contemporary housing clusters utilizing green technologies, such as solar panels, green roofs, and water recycling, culminating in the detailed design of eco-houses within urban orchard areas. The researcher aims to evaluate the projects using the LEED-ND rating system to assess the sustainability levels of selected academic projects, with the objective of examining the feasibility of implementing universal sustainability principles in local projects. The findings reveal numerous innovative academic projects that demonstrate two primary outcomes: first, the potential for implementing universal principles of urban sustainable neighborhoods in Iraqi cities, particularly Baghdad, to attain urban sustainability; and second, the imperative to establish localized Iraqi urban sustainability criteria and rating systems that align with the Iraqi environment and accommodate the

local microclimate [86].

### 3. Conclusions

An influential new movement is emerging to shape the future of cities by prioritizing environmentally friendly construction methods and their effects on local communities. To tackle environmental issues, improve community well-being, and promote social fairness, sustainable solutions are becoming more and more important as cities keep expanding. One way to lessen the impact that cities have on the environment is to use renewable energy, green building materials, and energy-efficient technology. Sustainable methods not only can improve the daily lives of residents but also cut energy consumption, improve air and water quality, and create lively, walkable neighborhoods specifically for low-income earners. Future urban development can follow these suggestions for a more sustainable path, and regions such as Dhofar may improve their resilience, inclusiveness, and environmental consciousness by incorporating sustainable principles into planning and policymaking. Effective technologies and a wide range of less suboptimal building practices must illuminate hard policy choices. The focus should concentrate on the comprehensive aspects of sustainable housing, encompassing both new and existing structures within diverse cultural, economic, and environmental contexts. Designing ideal building concepts that minimize energy consumption and environmental impact requires meticulous planning and optimization. The design provides a genuine opportunity to decrease material costs and, more specifically, operational costs by shifting the focus to environmentally friendly and sustainable buildings. Hence, it is critical to employ a methodical procedure while choosing technologies to build sustainable eco-houses.

#### Authors' contribution

Marwan Ahmed Bait Farhan drafted and wrote the manuscript. He also did the analysis and literature survey. Dr Aiman Bin Mohd Rashid and Muhammad Faizal bin Abdul Rani revised the manuscript and supervised the writing of the manuscript.

#### Declaration of competing interest

The authors declare no conflicts of interest.

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#### Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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