

Key Performance Indicators (KPIs) for Assessing Sustainable Homes: Towards the Establishing of a Sustainability Index – The Case of Libya

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تاريخ الاستلام: 2026/04/01 تاريخ المراجعة: 2026/04/30 تاريخ القبول: 2026/05/13- تاريخ النشر: 2026/06/01

Abstract: Construction is a major contributor to environmental problems, including excessive consumption of natural resources and pollution of the surrounding environment. However, research aimed at minimising these adverse impacts remains fragmented. Assessment processes are dominated by a single merely monetary based approach which is insufficient to handle the current problem. Sustainability Assessment Methods (SAMs) have emerged to transcend the financial perspective and target the construction performance over multiple dimensions of social, environmental as well as economic aspects. Although a wide variety of sustainability assessments have existed in literature at the international level, little systematic effort has been applied to develop methods for assessing construction performance in the specific context of Libya. Hence developing a national assessment scheme is becoming necessary due to the considerable environmental, social and economic problems, along with poor resources and their inefficient use. This article is an attempt to fill this gap, aiming to contribute to better comprehension of the concept of sustainable homes and foster a paradigm shift through developing an integrated, structured set of Key Performance Indicators (KPIs) to be used for assessment of public housing development projects. This aim has been achieved through satisfying three objectives: integrated analysis of four well-known assessment tools from various countries across the world, a focus group interview with various stakeholders, and a large-scale questionnaire. Recommendations are proposed which aim to enhance the performance of public housing projects and promote the change towards more sustainability.

Keywords: sustainable homes; sustainability indicators; Sustainability Assessment Models; Libya.

1. INTRODUCTION

The construction industry is among the most resource-intensive worldwide, and its impacts on both humans and ecosystems are increasingly concerning. According to the Worldwatch Institute's (2003) report, building construction and operation is responsible for 40% of the world's total energy use, 30% of raw materials consumption, 55% of timber harvests, 16% of freshwater withdrawal, 35% of global carbon dioxide (CO₂) emissions and 40% of municipal solid waste sent to landfill. These sustainability-related problems are interdependent and present serious challenges that are shaping our future (RIBA, 2014). A radical shift in thinking is required to ensure sustainability of the available resources and protect our increasingly threatened environment.

According to Sune (2022), Susanti *et al.*, (2020), Higham and Stephenson (2014) and Ding (2009), developing and using Sustainability Assessment Methods (SAMs) is one of the solutions that foster the shift towards a more sustainable built environment. As Ahmed *et al.* (2015), Alyami *et al.*, (2013) and Ali and Al Nsairat (2009) point out, it is essential for the industry to have regular evaluations and assessments, thereby allowing the collation of evidence related to changes and impacts which might affect the environment. SAMs are perceived as a technique for promoting environmentally conscious construction while superseding mandatory standards in favour of sustainability-driven approaches (Ding, 2009; Fenner & Ryce, 2008). Although a wide variety of sustainability assessments have existed in literature at the international level, little systematic effort has been applied to developing methods for assessing construction performance in the specific context of Libya.

Libya's construction investments clearly require more development of indicators related to sustainability. Despite calls from academia (Elgadi *et al.*, 2016; Shawesh, 2016; Shibani & Gherbal, 2016; Ahmed *et al.*, 2015; Gherbal, 2015) for a paradigm shift away from assessment schemes limited to economically driven criteria, overarching sustainability-led assessment systems are still rarely used. Other authors emphasizing the urgent need for research on a set of standards for sustainable buildings in Libya include Elgadi *et al.* (2016), Shawesh (2016), Shibani and Gherbal (2016) Shebob (2012), and Almansuri *et al.* (2009), who have corroborated previous studies from Ngab (2007), UPA (2006) and El-Hasia (2005). Collectively this body of literature strongly argues that sustainability-based performance indicators for Libya's buildings should be identified, and their compliance benchmarked against fundamental

principles of sustainable development. Recent studies on residential energy use in Libya show that air conditioning is still one of the main reasons for high household electricity demand, especially during the summer when cooling needs are at their highest. For instance, Alafya and Maka (2025), case study used survey data and modelling to look at electricity use linked to cooling in Libyan homes. Their study highlighted the need to reduce energy demand through better building design. Similarly, Albarssi et al. (2025) reviewed research on energy retrofitting for residential buildings on Libya and nearby Mediterranean countries. They found that there is still limited research focused on these issues specifically on Libya. The present article is an attempt to fill the knowledge gap on sustainable building in Libya and to help to develop an integrated, structured set of Key Performance Indicators (KPIs) to be used for assessment of Libyan public housing development projects. The three parts of this paper will present an overview of the concept of sustainable homes in Libya, highlight the methodology used in this study, and discuss the results obtained.

2. LITERATURE REVIEW

Concept of sustainable homes in Libya

Sustainability-orientated thinking requires a balanced approach that considers environmental, social and economic issues. The sustainable home as a concept refers to homes that are designed to minimise the overall environmental impact, both during and after construction, in such a way as “to meet the needs of the present, without compromising the ability of future generations to meet their own needs” (Svensson & Wood, 2003). In response to such objectives, many national institutions have been created, for instance ‘The Libyan National Centre for Standardization and Metrology’ (LNCSM) and ‘Research Centre for Building Materials and Construction’ (RCBC); these devote their efforts to encouraging contractors to adopt sustainable development and producing environmentally friendly products through spreading awareness and through consultation services (UPA, 2006). In this regard, the Ministry of Housing and Utilities (MHU, 2015) states the following broad guidelines and principles which reflect to some extent a sense of sustainable development: (i) adequate locations and quarters are to be allocated to the new housing investments for private and public sectors with reasonable prices; (ii) efficient physical integration of the housing projects with the basic services and utilities such as schools, hospitals, gardens; (iii) suitable design of houses taking into consideration the space and living system of the potential owners; (iv) the harmony of building designs with the surrounding environment as well as utilising the locally available building materials; and (v) rigorous policies regulating the housing construction processes to improve project performance and overcome the relevant

obstacles as well as conducting studies on minimising the project costs through optimising the support decision systems.

Despite these recently adopted initiatives and processes, environmental and social concerns continue to represent weak aspects in the quest for sustainability in Libya. In the housing sector these apparently relate to the lack of comprehensive assessment frameworks alongside clear, robust performance indicators.

Some Peculiarities of the Libyan Scene

It is useful to highlight some relevant idiosyncrasies that affect application of sustainable housing in the Libyan context. One specific challenge here is that Libyan residential buildings continue to depend heavily on-air conditioning, as Almansuri *et al.*, 2009 emphasise, and this consumes massive amounts of electricity as well as raising acoustic and health-related concerns. As reported, poor design of dwellings in hot countries like Libya leads to consuming nearly 80% of the total electricity for air conditioning and refrigeration purposes. Hence building design for good solar shading is an unusually important consideration in Libya. As a result of the rapid population growth and a high level of economic growth and increased urbanisation, the residential housing sector not only is booming, but also accounts for more than half of the country's total energy demand, while the rest is shared by governmental (14%) and commercial (32%) use (Abdul-Rahman *et al.*, 2016). Figure 1 shows the electricity consumption by sectors in Libya.

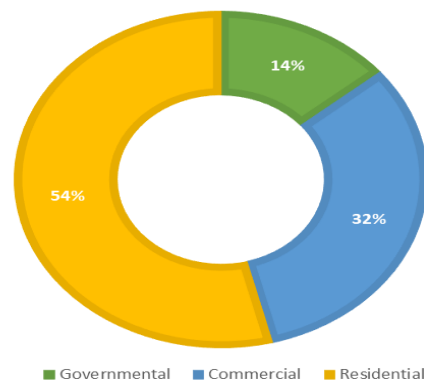


Figure 1: Electricity Consumption by Sectors in Libya. (Adopted from Abdul-Rahman et al., 2016)

In fact, with increasingly rapid ($\approx 7\%$ / year) growth in electricity demand, according to the Energy Information Administration's (EIA) report, Libya has become the fastest growing consumer of energy in North Africa (EIA, 2013). Another disappointing issue is that electricity

generation is entirely dependent upon the unsustainable practice of burning fossil fuels, which is now accepted as the main avoidable cause of climate change, but also has major environmental impacts on air, water and land (Abdul-Rahman *et al.*, 2016).

Regarding water use, Libya is one of the driest regions in the world and is facing serious challenges arising from rapid growth in water demand. Libya has no permanent rivers or lakes, and the country depends heavily on desalination plants to bring water supplies to a population scattered across a very large area. According to Ngab (2007), Libyan homes consume approximately 28% of all the water used in Libya, the rest of which is dominated by the agricultural sector (70%), whilst the industrial activities count for only 2% (see Figure 2).

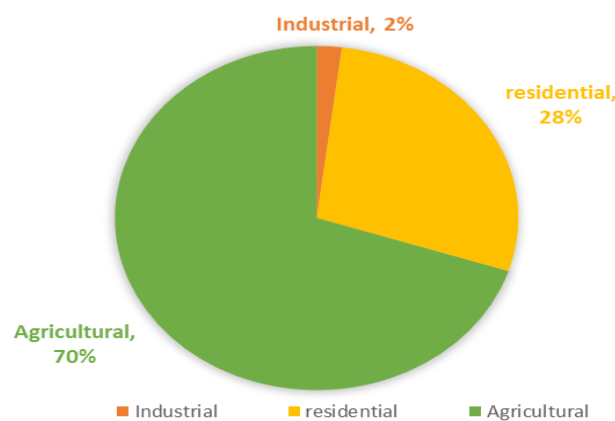


Figure 2: Water Consumption by Sector in Libya. (Adopted from Ngab, 2007)

Evidently there is a pressing need to improve the efficiency of energy and water consumption in Libyan dwellings through the application of sustainable home principles. Recent studies (e.g. Elgadi *et al.*, 2016; Mohamed, 2013; Almansuri *et al.*, 2009) indicate that heavily subsidised electricity and water prices have created a lack of awareness of resource consumption and environmental concerns, paralleling only limited development of applicable regulations and policies. These factors are believed to be amongst the most significant barriers to promoting the concept of Sustainability in housing investments in Libya.

In addition to the energy and water crises, according to Almansuri *et al.* (2009), the size of contemporary Libyan house lots is another pressing issue. The design of Libyan dwellings tends to lay stress on a luxurious style of living without paying adequate attention to the principles of sustainable housing design. The new Libyan dwelling development schemes are spacious, taking larger plots of land because villa forms of building are the preference of many homeowners, and their spaces exceed the average in many other countries (Elgadi *et al.*, 2016). As a result of this prevailing preference along with the increasingly rapid population growth, it

is becoming too expensive to obtain a sufficient plot of land for housing. Not only have government subsidies shrunk, but also the prices of building materials are continuously increasing. Furthermore, Elgadi *et al.* (2016) point out some issues related to invasion of privacy that have arisen as a result of the contemporary homes movement in Libya. For instance, it is argued that recent building regulations allowed apartment complexes to have more storeys than they used to have, without placing any restrictions on the number of windows and balconies on elevations. The privacy of low-rise buildings has, therefore, been invaded by these high-rise buildings (Mohamed, 2013). Another design-related fault identified in the literature is the extensive use of glass as a material for building facades, as residents started to complain about the glare caused by the harsh sun. Although reflective glass can be used, it still cannot bear the intensity of the sun's heat. Consequently, the building gains heat through the glass which leads to a greater use of air-conditioning. The cleaning requirements for a glass facade can also be problematic (Elgadi *et al.*, 2016).

Most importantly, a major problem facing Libyan homes is the lack of a proper building code, which aligns with a general lack of awareness of the potential benefits of sustainable homes; it is fuelled by a mere focus upon initial costs as opposed to a multi-dimensional appraisal of housing projects, as argued by Higham and Stephenson (2014). Recent evidence confirms that energy efficiency, water security and climate resilience should be central to sustainable housing indicators in Libya. The National Strategy for Renewable Energy and Energy Efficiency 2023–2035 supports reducing electricity consumption and increasing renewable energy use, which strengthens the need for KPIs such as passive cooling, envelope performance and solar readiness (National Economic and Social Development Board, 2023). Water efficiency is also increasingly important, as Libya's 2026–2050 National Water Security Strategy focuses on reducing consumption, limiting dependence on non-renewable groundwater and improving water-loss control (UNDP Libya, 2026). In addition, the 2023 Derna floods showed that future housing indicators should also consider flood risk, drainage, emergency access, climate adaptation and long-term maintenance (Buijlayyil *et al.*, 2025). This study, therefore, aims to fill this gap through developing a composite sustainability index for residential buildings in the Libyan context.

3. RESEARCH METHODOLOGY

The study started with a review of previous work and sustainability assessment indicators developed by well-known institutions, namely BREEAM (Building Research Establishment Environmental Assessment Methods); LEED (Leadership in Energy and Environmental Design), GBCA (Green Building Council Australia), DGNB (German Sustainable Building Certificate). These have been established in various regions of the world, respectively UK, USA, Australia and Germany, and provide integrated schemes for assessing sustainability in housing projects. They may be partially adaptable to the Libyan context, making allowance for its special features. The main part of the present work aims to make a reliable synthesis of inputs from experts that have directly applicable knowledge and experience. This type of data is well-handled by a mixed methods approach, which involves qualitative and quantitative techniques and has been adopted here. The empirical stage of this study was therefore launched with a focus group interview, with the aim of identifying the most important sustainability interventions for Libyan homes. A large-scale questionnaire survey was the second principal method of the study, allowing engagement with a wide spectrum of practitioners, professors and administrators, who are well-experienced in both the scientific community and the practice fields relevant to the context of Libya's built environment. In this respect, the Key Performance Indicator (KPI) was initially accepted based on its having a mean rating that is equal to or exceeds 3 out of 5 on the adopted Likert scale (i.e. 1 = not important; moderately important; not sure; important; 5 = extremely important) so that it is recognised as among the most applicable for assessing sustainable homes in Libya.

4. FINDING AND DISCUSSION

Based on analysing the data collected, seven main categories were raised for assessing sustainable homes in the Libyan context. As Figure 3 shows, the judgement of participants is that the categories 'Energy Efficiency' and 'Water Efficiency' are almost at the same level and they are the top priorities. These are compatible with current concerns in relation to the Libyan built environment regarding water use challenges and renewable energy potentials, specifically solar energy (MWR & CEDARE, 2014). The next most important priorities include 'Materials Efficiency', 'Health and Wellbeing' and 'Waste and Pollution'. In some cases, these categories are sometimes closely linked. For example, the criterion of 'Waste Treatment and Recycling' from the 'Waste and Pollution' category can also affect the user comfort of 'Health and Wellbeing' criterion. The categories of 'Management and Process' and 'Location Quality'

achieved almost the same level of importance but at the bottom of the list. However, all these categories, as agreed by the participants, are essential for the establishment of a coherent and comprehensive scheme to evaluate the sustainability requirements of Libyan housing projects.

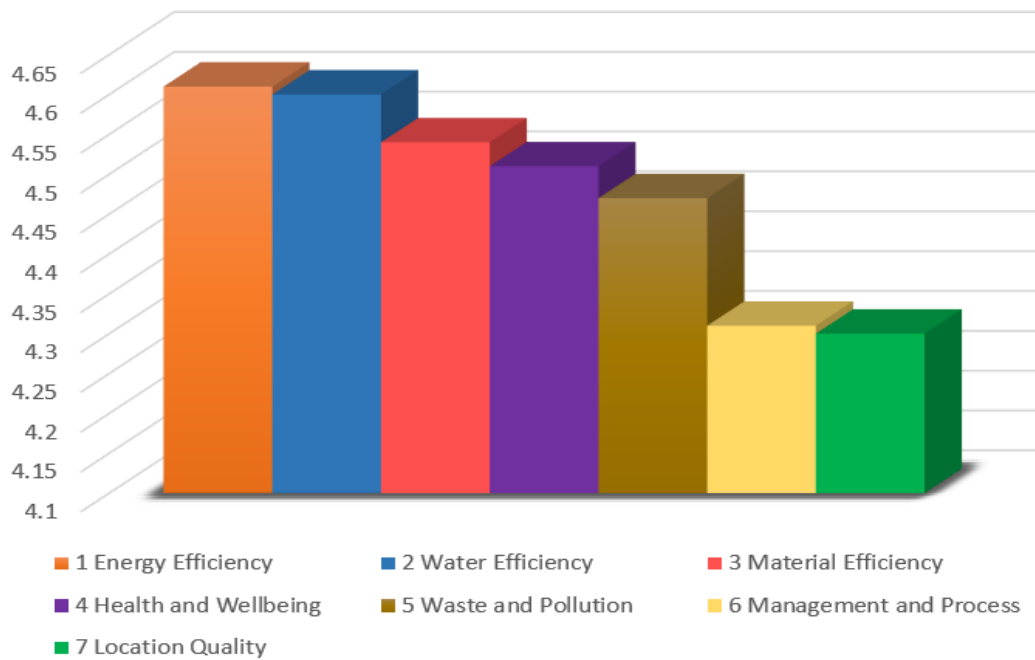


Figure 3: The Relative Importance for the Set of Categories

The findings revealed that each assessment category could be identified by a number of individual criteria, referred to as Key Performance Indicators (KPIs). Their number varies between categories, according to the inherent nature of the category itself and its importance as recognised in the local (Libyan) context. Figure 4 shows the relative importance of the 43 KPIs grouped into the seven clusters: (a) Management & Process; (b) Material Efficiency; (c) Energy Efficiency; (d) Water Efficiency; (e) Health & Wellbeing; (f) Waste & Pollution; (g) Location Quality.



Figure 4: The Relative Importance of the Seven Sets of KPIs

a) Management & Process Indicators

Somewhat surprisingly, the results showed that this category 'Management and Process' was rated sixth out of the seven categories, as its mean scored 4.31 out of five-rate score 'important'. The principal purpose of this category is to minimise the potential adverse impacts on site development, with ecological care ensured through the management and control of soil erosion, watercourse sedimentation and biodiversity protection. There is an increasing acknowledgment that management and process aspects are vital to encourage the adoption of sustainable development practices throughout the design, construction, commissioning and handover stages in order to ensure that robust sustainability objectives are set and implemented. The category of 'Management and Process' encompasses six indicators. The respondents generally reflect the principal goal of the sustainability-based managerial considerations within the home projects, including the minimising of life cycle costs and the reduction of the potential impacts of construction activities on site development and the ecosystem. Although there was not a significant difference between variables, it is clear that the highest scored feature was the criterion of 'Minimising Life Cycle Cost', with a mean of 4.54 'Extremely Important'. Following this, the respondents' considerations were in favour of the issues of 'Environmental Management Plan', 'Ecosystem Enactment', and 'Potential Natural Risks'. These indicators received mean values of 4.46, 4.46 and 4.44 respectively. Meanwhile, the least significant managerial issues were the indicators related to 'Independent Commissioning Agent' (3.77) and 'Integrative Process' (3.75).

The Management and Process category should be updated to reflect the growing importance of governance, post-occupancy evaluation and links with national sustainability targets. Libya's renewable energy strategy for 2023–2035 focuses on improving energy efficiency and increasing renewable energy use, while the 2026–2050 National Water Security Strategy aims to improve long-term water management and climate resilience. This suggests that sustainability in housing should not only be assessed at project level, but should also be linked to wider national energy and water priorities (National Economic and Social Development Board, 2023; UNDP Libya, 2026).

To ensure that the quality of the project management and process is optimal, several indicators, as suggested by USGBC (2013), can be used to evaluate the extent to which the relevant general conditions have been established early in the project. These include, for example, evaluating the extent to which requirements planning has been undertaken; measures implemented to inform the public; conducting the durability risk evaluation; putting a quality management

process in place; adopting a BIM approach (Building Information Modelling); promoting the adoption of Lean construction techniques; and the integration of a detailed description of sustainability requirements within the specifications.

b) Material Efficiency Indicators

The results showed that this category was rated as ‘extremely important’, with a mean of 4.54, and third among the seven categories given. An essential objective of sustainable home building is to guarantee the optimum practice in terms of construction materials. The choice of building materials is important for sustainable homes because of the extraction, processing, and transportation they require. Activities to produce these materials may pollute air and water, destroy natural habitats, and deplete natural resources, so a more efficient process is inevitably required. Material efficiency, as a concept, means achieving more with less by using fewer resources (or less scarce resources) to accomplish the same goals (Cole, 1998). There is an increasing acknowledgment that housing providers should focus on the materials that go into - or come out of - a project that encourages steps to reduce the adverse impact of construction materials through its lifecycle. As Cole (1998) asserted, certain resources are becoming extremely rare, and the use of remaining stocks should be treated cautiously. He called for the substitution of rare material with more plentiful or renewable materials. The category of ‘Material Efficiency’ encompasses four indicators. As would be expected, the highest scored of these concerned the choice of materials with environmentally friendly impacts, and the materials reuse and recycling, since they recorded a mean of 4.55 and 4.48 respectively. The participants also agreed that responsible sourcing of materials is an important issue, scoring a mean of 4.44, whilst the issue related with the locality of material used came last in this category, achieving 4.35 out of five-point rating scale. This corresponds to a great extent with other authors (e.g. Susanti *et al.*, 2020; Tupenaite *et al.*, 2017; Alyami *et al.*, 2013) who have emphasised material efficiency as one of the most important criteria for assessing sustainability. Besides the economic benefits, using locally available materials efficiently avoids the harmful effects of long-distance transport. A substantial amount of energy is used to transport materials from manufacturing plants to home construction sites. Choosing local products, as Akadiri (2011) demonstrated, will reduce the use of embedded transportation energy associated with construction, smaller amounts of emissions will be produced, and less congestion will be encountered.

c) *Energy Efficiency Indicators*

As expected, this category 'Energy Efficiency' was one of the top priorities for sustainability in home projects, recording a mean of 4.61 'extremely important'. Energy efficiency is the utilisation of less energy to provide the same service. The need to use energy more efficiently is now well recognised in most countries, and housing projects have a leading role in meeting such a need. The principal purpose of this category is to assess measures that ensure improvements within the inherent energy efficiency, thereby reducing carbon emissions and supporting the efficient use throughout the home's life. The category of Energy Efficiency encompasses eight indicators. Renewable energy and alternative strategies, efficient HVAC systems, use of thermal insulation, and primary energy demand, all emerged as the top four issues for the main category of Energy Efficiency. These indicators achieved a level of 'Extremely Important' with mean values of 4.57, 4.55, 4.51 and 4.50 respectively. The respondents also recognised the importance of shading strategy use along with sunlight access as ways of promoting the use of greener energy. These two indicators recorded mean scores of 4.49 and 4.35, respectively, and were rated as 'Important', while the two lowest degrees of agreement related to the features of appliance efficiency and hot water systems with 4.33 and 4.29, respectively.

According to IEA (2022), the relevant indicators date from 2016 which is the most recent year for which comparable data are available. Libya was ranked 99th globally in relation to electricity consumption, using 28.48 billion kWh which means 4,680 kWh per capita. The average Libyan consumes roughly twice as much electricity as the average Indian person, but only about one quarter of the UK average. Likewise, in relation to natural gas consumption, Libya in the same year, was ranked 60th globally, consuming 4.49 billion m³ which means 704.36 m³ per capita. The average Libyan consumes roughly twice as much natural gas as the average Indian person, though still about 70% of the average in the UK (IEA, 2022). According to Almansuri *et al.* (2009), air conditioning consumes about 80% of the energy used in Libyan homes. An HVAC system is likely to be critical to homeowners, and the need to adopt efficient systems has been well reflected in many publications (e.g. Sune 2022; Susanti *et al.*, 2020; Tupenaite *et al.*, 2017; Abdul-Rahman *et al.*, 2016; Akadiri, 2011), which have corroborated the current finding. Optimising home design can help to achieve better energy performance. This could involve, for example, the consideration of passive systems that use natural light, air movement and thermal mass as well as producing energy from renewable resources. Among the benefits of assessing these features are promoting operational practices that reduce peak

demand on electricity supply infrastructure, pushing the home's peak demand performance to meet the network's peak demand ratio benchmark.

d) Water Efficiency Indicators

Water issues received consideration attention from the respondents. The results showed that this category 'Water Efficiency' was rated second after the category of Energy Efficiency, with a mean of 4.60 'extremely important'. This reflects the great demand for water that housing developers and providers should consider. It also aligns with Ali and Al Nsairat's (2009) findings that water issues are the top priorities in Jordan. Water efficiency management has an essential role in helping to ensure a sufficient water supply volume, for people, the economy and the environment, both now and in the future. This can be achieved by restricting water use and reducing water wastage through carefully metering the amount of water required for a particular purpose and the amount of water used or delivered. Six different issues were suggested for inclusion in this category and those related to potable water quality and rainwater harvesting received the highest degrees of agreement amongst the respondents. They recorded respectively 4.57 and 4.54 as mean values 'Extremely Important'. It was not surprising that the criteria associated with potable water demand and water appliance efficiency were also considered viable ways of reducing the overall water consumption, achieving 4.46 and 4.33. However, issues related to the greywater system efficiency and, perhaps more surprisingly, the irrigation system use recorded the lowest and similar values of mean importance at 4.29.

As MWR and CEDARE (2014) reported, Libya relies almost completely on non-renewable, fossil, groundwater resources. With very limited perennial water resources, namely only ephemeral rivers or wadis, the Libyan government has undertaken a massive project, known as the Great Man-Made River Project (GMMR). This provides approximately 6.5 million m³ of freshwater per day to supply water for the Northern cities of Libya, which accommodate around 70% of Libya's population (Abdudayem & Scott, 2014). The figures indicate that in 2012, the most recent year for which data are available, approximately 5830 million m³ of fresh water was withdrawn from reservoirs and underground aquifers; of this, 20% was used domestically and over 50% for flushing WCs and washing. Groundwater (including fossil groundwater) provides over 95% of the water withdrawn, whilst the remainder is divided between surface water, desalinated water and wastewater (Abdudayem & Scott, 2014). The national targets indicated that a sustainable groundwater abstraction should not exceed 3650 million m³/year, although only 650 million m³/year comes from renewable groundwater and 3000 million m³/year from fossil water (CEDARE, 2014). Because fossil groundwater is not included in the

renewable water resources, the current water withdrawal is more than eight times the annual renewable water resources, whilst more than half of the domestic water supplies were from the GMMR (MWR & CEDARE, 2014). Accordingly, people in Libya are not charged for water use, as water supplies are taken for granted. This, as Abdudayem and Scott (2014) asserted, has led to unconscious behaviour regarding consumption of water and lack of regard for this resource, which results in even further waste and less efficient distribution. Recent policy developments highlight the importance of water efficiency in Libyan housing. Libya's 2026–2050 National Water Security Strategy focuses on reducing water use, improving water management, cutting network losses and reducing reliance on non-renewable groundwater. This shows that housing indicators should go beyond efficient appliances and also include water monitoring, leak detection, reuse systems and changes in user behaviour. Thus, potable water demand could be better assessed using a smart meter that allows control of the occupant's water consumption and wastewater volume.

e) Waste & Pollution Indicators

The results showed that this category 'Waste and Pollution' was rated fifth among the set of categories, with a mean of 4.47 'important'. The principal purpose of this category is to address the prevention and control of pollution associated with the home's location and use. Concern has been growing in recent years about the adverse effects of waste on the environment. Assessing the hazardous emissions and pollutants, as well as the potential natural risks, is considered vital to establishing sustainable homes. In this respect, the category of Waste and Pollution encompasses five indicators. The most common features of waste and pollution that appear important among participants were the issues related to the waste treatment and recycling facilities. This criterion recorded 4.55 'Extremely Important'. Interestingly, the participants agreed that the protection from sandstorms is a unique criterion, particularly relevant for the built environment in the Libyan context. It scored 4.37, 'Important'. Similarly, the rest of the indicators (i.e. Polluted Emissions Reduction, Low Refrigerants Rate, and Low Light and Noise Pollution) revealed a closer degree of agreement at 4.36, 4.34 and 4.27 respectively. This appears to validate the view expressed by Alyami *et al.* (2013), who also emphasised that the provision of efficient waste recycling systems is essential to assess environmental sustainability.

In Libya, the Ecological Protection Agency (EPA) stated that the landfill situation is now critical, with local authorities having to resort to transporting waste further afield or to burning it, and thus releasing pollution into the air (Jain, 2013). According to Elgadi *et al.*, (2016),

approximately 28 million tonnes of municipal waste was generated in Libya in 2016, and 15 million tonnes of this was collected from households, which is more than half a tonne of household waste per person. Ahmed *et al.* (2015) recommended that the size, type and number of containers should be set out by the Libyan local waste collection authority to ensure best practices in this respect. Particular attention should be paid to: increasing waste diversion; reducing non-recyclable household waste to a level below the recognised norm; providing an external storage space for household recyclable materials; and providing an appropriate combination of adequate internal space for their storage of recyclable materials. As stressed by Jain (2013), consideration of waste efficiency within housing projects not only reduces the environmental impacts but also raises awareness and generates behavioural change across homeowners. Recent research also shows the need to give more attention to the Waste and Pollution category. Alossta *et al.* (2024) studied construction and demolition waste management in Libya and found that effective strategies need to be affordable, socially acceptable and environmentally responsible. This is particularly important as reconstruction and infrastructure development in Libya could produce large amounts of construction and demolition waste. Wider research also suggests that digital tools can improve waste tracking, recycling, decision-making and circular-economy practices in developing countries. Although this research is not Libya-specific, it is still relevant, as Libya could benefit from stronger digital records, material tracking and better site waste planning (Muzioreva, Musonda and Gumbo, 2026).

f) Health & Wellbeing Indicators

The Health and Wellbeing category has a strong bias towards social aspects of the benefit evaluation of sustainable homes, as it mainly revolves around enhancing safety and comfort assessments and thereby increasing occupant satisfaction. Nonetheless, this category of does not attract as high a priority as might be expected. This can be explained by a greater orientation in favour of other aspects such as energy and material efficiency for assessing sustainability in the housing projects. The category was rated fourth, with a mean recorded of 4.51 ‘extremely important’. Its principal considerations are to provide a suitable healthy level of sound and light, and such microbes and allergens as may be released from interior or external elements. The category of ‘Health and Wellbeing’ encompasses nine indicators, where the three rated as most significant reflect both the importance of measures needed to deal with the harshness of the Libyan climate that necessitates the operation of cooling systems, and the needs for home developments where people feel safe and secure. This was clear through the mean scores recorded for the indicators of ‘Cooling and Heating Comfort and Control’, ‘Natural Ventilation

Level' and 'Safety Protection and Fire Security', which were 4.53, 4.52, 4.52 respectively. Furthermore, the issues related to 'Illumination Quality', 'Internal Layout Functionality', 'Cultural and Architectural Heritage Considerations', and 'Sound Absorption and Insulation' were all deemed to be more important than other features such as 'Maintainability and Flexibility' or 'View Out and Aesthetic Aspects', as the average mean of the former group was roughly 4.30 whilst for the others it was 3.78.

Ventilation and illumination quality have been considered the key components amongst the health and wellbeing cluster as they are probably the criteria on which most, if not all, publications about sustainability (e.g. Sune 2022; Susanti *et al.*, 2020; Tupenaite *et al.*, 2017; Alyami *et al.*, 2013; Ali & Al Nsairat, 2009) have agreed. They mainly help to improve the overall quality of a home's indoor environment by encouraging installation of an approved bundle of air and light quality measures. The World Health Organization (W H O) reported that most of an individual's exposure to many air pollutants comes through the inhalation of indoor air (WHO, 2010). Hazardous household pollutants include carbon monoxide, radon, formaldehyde, mould, dirt and dust, pet dander, and residue from tobacco smoke and candles (Iesa *et al.*, 2017). According to Iesa *et al.*, many of these pollutants can cause health reactions in the estimated 17.8% of Libyan people who suffer from asthma and the approximately 30% who have allergies. Housing providers can help to create a healthy, non-toxic environment by having appropriate procedures in place to identify and manage risks. Many measures have been recommended in various publications (e.g. DGNB, 2022; USGBC, 2013), including air exchange rates; airspeed within the permitted value; installation of verified dehumidification equipment; measurement of volatile organic compounds (VOCs); the design of passive ventilation systems approved by a licensed HVAC engineer; installation of a whole home active ventilation system that complies with a verified standard; and installation of local exhaust systems in all bathrooms and the kitchen. Parallel measures to reduce adverse light conditions can also reduce subsequent social costs. According to Tupenaite *et al.* (2017), flickering lights, lights that poorly render colour, and discomfort from glare, can result in a number of negative health impacts for home occupants, such as headaches, general fatigue and eye strain. It is important to consider that different spaces and activities require different amounts of ventilation and illumination, as can be ensured by well-qualified design teams.

g) Location Quality Indicators

Very surprisingly, the results showed that the category ‘Location Quality’ was rated last among the set of categories, yet its mean scored 4.30, i.e. ‘important’. This category promotes a home location that facilitates easy access to local services and amenities and reinforces the satisfaction and productivity of home occupants. It should also reduce the environmental, social and economic impacts of multiple or extended home occupants’ journeys, including transport-related emissions and traffic congestion. Schemes satisfying this criterion are expected to ease availability to public services and important facilities and provide suitable provision for road users, including drivers, cyclists and pedestrians. In this cluster, the data suggested that five performance indicators should be considered for their importance in assessing ‘Location Quality’ of housing projects. The prioritised issues highlight aspects associated with community services and those enhancing the technological connectivity in relation to the concept of ‘Smart Homes’. These indicators recorded 4.54 and 4.51 respectively ‘Extremely Important’. Following this, considerations of transportation and car parking capacity were significantly targeted within the sustainability agenda to improve accessibility for homeowners; both scored 4.25 ‘Important’. Unsurprisingly, the issue of pedestrian and cyclist safety did not receive as much agreement by the respondents as the rest of the Location Quality group, even though their mean scored 4.16, ‘Important’. It is clearly shown that ‘Community Services and Facilities’ appears at the top of the list of Location Quality criteria. This accords with the studies of Higham & Stephenson (2014) and Alyami *et al.* (2013), who emphasised the choice of community services as one of the most important criteria for assessing the social features of sustainability. Community Services and Facilities include: (a) Public infrastructure (e.g. electricity, gas, sewers, water supply and transportation); (b) medical services (e.g. hospital, pharmacy, dental clinics, etc.), education services (e.g. kindergarten, school, higher education, etc.), leisure services (e.g. cinema, theatre, galleries, library, community centre, etc.), fitness services (e.g. gymnasium, playgrounds, sports hall, etc.); (c) commercial infrastructure (e.g. supermarket, bakery, butcher, laundry, etc.); food and catering (e.g. restaurant, café, etc.); and (d) Other services (e.g. bank, post office, hairdresser, fitness studio, wellness facilities, fire station, police station, place of worship etc.). Amer (2007) asserted that social capital is closely allied with social cohesion and civic engagement and is an important factor for community development. His definition of social capital involves the structures that help to maintain and develop human capital in partnership, such as families, communities, businesses, trade unions, schools and voluntary organisations. (However, a near absence of trade unions is another

idiosyncratic feature of the Libyan social environment.) As the World Health Organization (WHO, 2010) stressed, higher levels of social capital bring higher rates of economic growth, lower crime, better health and better government. One way in which housing providers can contribute to the increase in social capital is by selecting high quality locations for their projects, which do not only provide good infrastructure but also make all human services reachable. To complete this part of the project, Figure 5 provides a compact summary of the proposed categories and KPIs, and their suggested prioritisation. This has been termed the Libyan Sustainable Housing Assessment Model (LSHAM).



Figure 5: The LSHAM Scheme for Sustainable Homes (More important indicators are shown closer to the centre)

5. CONCLUSIONS

Determining a set of KPIs for assessing sustainability in housing projects in Libya was the key objective of this study, as no existing comprehensive framework including all three aspects of sustainability was found, either in practice or in the literature. The prior lack of a building code specific to Libya was also noted.

By integrating indicators from different well-established Sustainability Assessment Models (SAMs), this research built on the strengths of each and should provide a more holistic assessment framework. Nevertheless, several peculiarities of the Libyan scenario were revealed and these made it clear that careful attention to local context would be essential. Examples included the extreme dryness of the country, excessive reliance on air conditioning, and invasion of privacy from buildings that overlook others.

Reliability of the gathered data and robustness of consequent deductions, especially regarding orders of priority, were enhanced by the mixed methods of surveying, the substantial number of respondents, and the statistical methods of analysis. A large-scale questionnaire survey was carried out to consolidate the findings from the integrated analysis of the four well-established systems (BREEAM, LEED, GBCA, and DGNB) and the focus group interview, thus enhancing the reliability of the data whilst also providing a comprehensive model of sustainability for housing projects. As Figure 5 visualises, the framework of sustainability for assessing home projects has emerged by investigating a wide range of professional and academic views from different sectors including housing providers, local authorities and academia, encompassing a set of 43 KPIs grouped into seven broad categories (i.e. Management & Process; Materials Efficiency; Energy Efficiency; Water Efficiency; Waste & Pollution; Health & Wellbeing; Location Quality). This clearly supports the significance and validity of the identified KPIs to shape sustainability-based interventions within the housing investments. The investigation of the sustainability indicators shows that, although there are similarities at the category level between the international assessment models, some indicators were added and others were omitted, depending on their importance according to the local context of Libya. The findings of this research revealed that because of the shortages of natural resources, the categories of “Energy Efficiency” and “Water Efficiency” are the top priorities for housing projects in Libya. “Management & Process” and “Location Quality” were ranked as less significant, but still important indicators.

It is suggested that this framework can produce significant benefits that are not likely to result from standard practices, as well as maximising beneficial social and economic impact, rather

than merely concentrating on the more conventional approach of minimizing environmental impact. However, the set of KPIs is still in its infancy and further study is required to ensure the viability of this framework as an assessment tool for measuring sustainability in housing development. The developed set of indicators could usefully be subjected to rigorous ranking systems through utilising an analytical technique such as AHP ‘Analytic Hierarchy Process’; this is being addressed in the authors’ ongoing research “A composite index for assessing public housing projects in Libya”. The researchers believe that the findings of this stage will provide solid information about the sustainability of public housing projects in Libya, allowing the establishment of the Libyan public housing projects’ commitment to sustainability by which the desired shift from a solely monetary based to a multidimensional approach is to be facilitated. It is also felt that they could support initial development of a Libyan national building code.

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