An-Najah National University

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DEVELOPING ENERGY AND WATER EFFICIENCIES RATING SYSTEM FOR EXISTING BUILDINGS IN PALESTINE USING THE ANALYTICAL HIERARCHY PROCESS (AHP)

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Dedication

To my wonderful parents, Mamoun Al Qudsi and Raghda Al Shalabi, who never left my side, lighted the way in front of me, and gave me nothing but love and care. I could never reach my dream without you.

To my beloved husband, Abdallah Aqel, who lifted me through the darkest days and supported me with the energy to fly when I couldn't walk, you are the perfect companion for a lifetime.

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I want to thank the experts who participated in the study and contributed their time and excellent suggestions to enhance sustainability in the built environment in Palestine.

Declaration

I, the undersigned, declare that I submitted the thesis entitled:

DEVELOPING ENERGY AND WATER EFFICIENCIES RATING SYSTEM FOR EXISTING BUILDINGS IN PALESTINE USING THE ANALYTICAL HIERARCHY PROCESS (AHP)

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher’s own work, and has not been submitted elsewhere for any other degree or qualification.

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Date: 10/09/2023

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Abstract

Green Buildings Rating Systems (GBRSs) are receiving much attention among governments worldwide, as they contribute to achieving the Sustainable Development Goals (SDGs) and enhancing the construction sector that is considered a significant contributor to Carbon Dioxide (CO_2) emissions and the depletion of natural resources. Buildings negatively impact the environment at each stage of their lifecycle, but the operation and maintenance phase accounts for 70% to 90% of all. GBRS provides project stakeholders and decision-makers with a road map and guidelines for enhancing the built environment sustainability and operational performance. Currently, there is no Palestinian GBRS for existing buildings, and the only rating system available targets new construction. This study aims to propose a GBRS for existing buildings in Palestine regarding two criteria: Energy Efficiency and Water Efficiency, as these categories cumulatively weigh 50% to 70% among most GBRSs. Six global and local GBRS were reviewed to develop the most significant energy and water categories sub-criteria to evaluate the 'greenness' of existing buildings. Twenty two Palestinian experts were interviewed to prioritize the developed sub-criteria in both categories, and the Analytic Hierarchy Process (AHP) was conducted as a multi-criteria decision-making approach to analyze responses using the Expert Choice software. The outcome of this study is a Proposed Palestinian Energy Efficiency and Water Efficiency Rating System for Existing Buildings (EX), which consists of a set of weightings and a four-level classification system, in which the AHP is responsible for the developed weighting system for the selected criteria and sub-criteria according to their priority. Finally, to ensure the validity of the developed system, a hypothetical case study in Palestine was evaluated using the Leadership in Energy and Environmental Design (LEED) for Operation and Maintenance (O+M), in addition to The Palestinian Energy and Water Efficiency based GBRS-EX. Results demonstrate the necessity for Palestine to have its rating version for existing buildings while customizing other GBRS versions cannot be used since GBRSs are influenced by the unique environmental and cultural characteristics of the nation where they are established. The study recommends further research to develop GBRS in Palestine that covers other categories and specific types of buildings.

Keywords: Green Retrofitting Strategies; Energy Efficiency; Water Efficiency; Analytic Hierarchy Process (AHP).

Chapter One

Introduction and Literature Review

1.1 Introduction

Nowadays, sustainability and sustainable development are considered the world's massive issues, especially with the uprising of environmental problems, climate change and their severe consequences, such as rising sea levels, seasonal changes, food poverty, also increasing natural disasters like wildfire, desertification, and floods (Al-Qawasmi et al., 2019). The construction industry continues to be a significant source of carbon dioxide (CO_2), which contributes to climate change and global warming. Growing construction activities raise CO_2 emissions into the atmosphere, whether through cement combustion, steel manufacturing, construction materials, or building machines operations (Musarat et al., 2021). Furthermore, the building industry is known for its high energy consumption causing environmental effects. Buildings consume one-third of total energy, and one-third of the world's resources, including 12% of all freshwater usage. Also, buildings generate 40% roughly of total solid waste volume (Dwaikat & Ali, 2016). Responding to these conditions, "going green" and "environmental sustainability" has been used to emphasize the necessity of sustainable building practices. Yet, the recent statistics show that the construction industry remains a large consumer of resources and energy (Pinkse & Dommisse, 2009). This could be related to different social and psychological barriers, including the constructions' stakeholder and decision makers' unresponsive attitude and opinions toward embracing sustainable and Green Building (GB) solutions (Darko et al., 2017).

Challenging the increasing energy prices and the rising environmental concerns evolved the need for sustainable and environmentally-friendly facilities. Governments and institutions created green building rating systems (GBRS) to optimize natural resources consumption and limit pollution (Doan et al., 2017). A GBRS presents a guideline and a tool to enable the project team to achieve sustainability, improve buildings' operational performance, and minimize the buildings' environmental impact (Awadh, 2017). Various rating systems are well known in the field such as LEED in the United States of America (USA), BREEAM in the United Kingdom (UK), Green Mark in Singapore, GreenShip in Indonesia, CASBEE in Japan, and others (Mahmoud et al., 2019). Most of these rating systems focus on new building with less attention to existing buildings (AbdelAzim et al., 2017). However, buildings negatively affect the environment at all stages of their lifecycle, but particularly the operation and maintenance phase accounts for 70%–90% of all effects on the environment (Sharma et al., 2011). Furthermore, new constructions represent only a small section of structures (Mahmoud et al., 2019). The awareness of sustainability as a project purpose complements the other components of value and benefits. As a result, an existing building must be assessed to specify measures that would significantly reduce its environmental impact (Ebrahimi et al., 2019).

The green evaluation of buildings is a complex task due to the large number of attributes involved, the qualities' parameters are diverse, several technical experts from various fields are required, and the method changes depending on geographical and climatic conditions. However, these constraints can be solved by applying multiple criteria decision-making approaches like the Analytical Hierarchy Process (AHP) (Vyas et al., 2019), which was adopted in this research to estimate the weights of criteria responsible for evaluating the 'greenness' of existing buildings. AHP is a mathematical decision-making method that provides an effective solution to deal with complex decision-making considering both qualitative and quantitative aspects of decisions. Also, AHP aids in the reduction of bias and helps avoid frequent team decision-making errors such as lack of concentration, preparation, involvement, or ownership (Ali & Al Nsairat, 2009).

In light of Palestine's current situation, the political implication, the scarcity of energy and other resources, and the country's rapid population growth, the significance of GBs and sustainable development research cannot be underestimated. Retrofitting existing buildings to enhance its sustainable performance would not only conserve resources, reduce pollution, and adverse impact on the environment, but will also help occupants satisfy their indoor quality requirements. As far as we know, there is no GBRS for existing buildings in Palestine. Also, according to Hazem et al., (2020) there is a lack of research on GBs in North African countries and the Middle East countries including Palestine, as 90% of these publications come from advanced countries such as the US, UK, Italy, and Singapore.

This study aims at developing Energy and Water Efficiency based-GBRS for existing buildings in Palestine considering its specific regional and climate characteristics. The study focuses only on the two categories of Energy Efficiency and Water Efficiency for the green evaluation of existing buildings because of the limited time available to complete the thesis requirements. The selection of these categories was motivated by the importance and focus they receive from GBRSs, where they collectively weigh nearly 50-70%. Also, the scarcity of natural resources in Palestine and the limited control over available resources due to the Political implications necessitate finding sustainable solutions to reduce existing buildings' consumption of energy and water.

Considering previous research, relevant data were collected from professionals and engineers working in Palestinians universities, construction and GB sectors through pairwise-comparison designed questionnaires filled through semi-structured interviews. This rating system is designed to evaluate existing buildings based on two main criteria: Energy Efficiency, and Water Efficiency, each were further subcategorized into several criteria. The AHP was adopted to weigh the importance of the defined criteria. To ensure the validity and applicability of the proposed system a hypothetical case study was evaluated using the developed system and the LEED for Operation and Maintenance (O+M), then after results were compared to investigate how the environmental factors influence the evaluation.

1.2 Theoretical Background

1.2.1 Green Building (GB) and Sustainability

Recently, researchers are becoming more aware of the building industry's negative impact on the environment. Buildings account for 40% of world resource usage, 30% of world energy consumption, and 40% of global waste creation (Akreim & Suzer, 2018). Furthermore, buildings account for over 40% of total carbon dioxide (Aktas & Ozorhon, 2015). As a result, GB has been proposed and advanced as a guiding model for sustainable development practices in the construction industry (Olubunmi et al., 2016). Even though "sustainability" and "green building" are frequently used interchangeably in the literature, they have distinct but related meanings (AbdelAzim et al., 2017).

The United Nations (UN) presents the most widely-recognized definition of sustainable development: ''development that meets the needs of the present without compromising the ability of future generations to meet their own needs'' (Wedding & Crawford-Brown, 2007). USA Environmental Protection Agency (EPA) defines sustainability as "to create and maintain conditions, under which humans and nature can exist in productive harmony, that permits fulfilling the social, economic, and other requirements of present and future generations" (Fiksel et al., 2012).

GB is the practice of building infrastructure that consumes fewer resources, has minimal negative impacts on the environment, and provides occupants with healthier indoor conditions (Chatterjee, 2015). GB design focuses on conserving resources and energy, material recycling, and enhancing the human life quality while sustaining ecosystem capacity in harmony with the traditions, local climate, surrounding environment, and culture (Wira et al., 2017).

The EPA presents a generally recognized definition of GB: "Green building is the practice of creating structures and using processes that are environmentally- responsible and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation and deconstruction" (Steinemann et al., 2018). Considering the presented definitions, a GB can be defined as designing, constructing, and operating the building to eliminate its negative effects on the environment. While sustainability is the general philosophy of utilizing resources responsibly regarding humans and the environment (AbdelAzim et al., 2017).

1.2.2 Green Buildings Rating Systems (GBRS)

Several building evaluation tools are available on the market designed for various types of projects and focus on different sustainable development elements. These evaluation tools can be classified into two main groups: Criteria-Based Systems and Life Cycle Assessment (LCA) methodology (Waidyasekara & Silva, 2013). A multi-criteria credit system assigns a certain number of points, within a given range, to each issue or topic in a series of distinct categories that are believed to affect the sustainability of the building. The latter process is a scientific way to evaluate a building's environmental impact, although it is more complicated than the criteria-based approach. Therefore, the multi-criteria system serves as the basis for the majority of GBRSs (Mattoni et al., 2018). The GBRSs were created by authorities and institutions to modify natural resources usage and reduce pollution. Certified buildings are considered more energy-efficient, provide a better living space, and contribute to the property's public image (Tien et al., 2017).

There are an estimated 600 GBRSs in use over the world. The BREEAM (Building Research Establishment Assessment Method, the United Kingdom (UK), since 1990) was the first to evaluate building performance using specific target values for several categories (Tien et al., 2017). There are other well-known GBRSs: LEED (Leader ship in Energy and Environmental Design, the USA, since 1998), CASBEE (Comprehensive Assessment System for Built Environment Efficiency, Japan, since 2001), Green Star (GS, Australia, since 2003), ASGB (Assessment Standard for Green Buildings, China, since 2006), PRS for Estidama (Pearl Rating System, Abu Dhabi Urban Planning Council, since 2008), etc. By selecting one tool, the user is obliged to utilize a specific model, such as definitions, weighting or scoring systems, and databases (He et al., 2018).

Boonstra and Pettersen, (2003) presented various green rating systems for existing buildings, as well as their respective strengths and weaknesses. For example, NABERS (National Australian Building Environmental Rating System) aims to provide Australia's first complete rating system for existing, operating structures. Eco-profile is a voluntary environmental grading system for buildings developed by a group of building owners, professionals, and researchers in Norway to evaluate existing commercial structures. Green Globes, on-line energy and environmental assessment tool in Canada, is part of the BREEAM/Green Leaf set of building assessment tools. Separate versions include the operation and administration of existing structures and the design of new structures. The most well-known system is LEED (O+M) for Existing Buildings which aim to verify that existing buildings' operations and management practices adhere to specified sustainable guidelines (Blumberg, 2012).

1.3 Problem Statement

The UN approved the Sustainable Development Goals (SDGs) on 25 September 2015, intending to eliminate natural and environmental catastrophes, eliminate hunger and poverty, eliminate discrimination and inequality, and eliminate international conflicts and wars by 2030 (Medvedkina & Khodochenko, 2019). Since then, governments globally have pursued sustainable development solutions in all industries, particularly construction. The built environment affects numerous local and global issues, such as demographic changes, global warming, land use, and energy and water shortage resources. The growing environmental awareness of the building impact highlights the significance of GB practice and the environmental assessments of buildings. According to the World Green Building Council: “ GBs can contribute to meeting the sustainable development goals ” and help achieve 9 of the SDGs listed by the UN (Alawneh et al., 2018).

While the Palestinian government imposes sustainability development in different fields like the industrial and medical sectors, its responsibility to support the SDGs is yet unfulfilled, particularly in the construction sector regarding the implementation of GB practices and the lack of GB research. Furthermore, the rapid population growth and the political implications in the Palestinian territory create pressure on water and energy resources. This is a serious call to embrace sustainability and GBs solutions in the construction industry in Palestine, especially to retrofit the built environment and enhance the existing building operational performance. Developing a green rating system provides project stakeholders with a roadmap and guidelines for improving building performance, conserving natural resources, and minimizing environmental impact. This research proposed a green rating system that focuses on existing buildings as there is no GBRS for existing buildings in Palestine. Moreover, there is a lack of research concerning enhancing the ‘greenness’ of the built environment and building retrofitting in Palestine. The Analytical Hierarchy Process (AHP) was adopted as this method had been approved to develop similar green rating systems in the literature.

1.4 Study Objective

The study aims at developing a green building rating system for existing buildings in Palestine concerning Energy and Water Efficiency and to propose evaluation criteria for such buildings.

1.5 The Importance of Study

Global concerns like climate change, global warming, the depletion of natural resources, and rising energy prices necessitate worldwide action to mitigate their impact on both the environment and humanity. The built environment is widely regarded as a crucial subject of attention for sustainable development. First, since buildings produce one-third of the world’s Greenhouse Gas Emissions (GGE), they are considered a significant source of CO_2 emissions. Second, buildings consume 40% of the world’s energy, 25% of water, and 40% of the resources (Kamaruzzaman et al., 2018). Establishing GBRSs for existing buildings will act as a roadmap for decision-makers and users to adopt sustainable practices and green retrofitting strategies in their properties.

Since there is no GBRS for existing buildings in Palestine, this study takes the first attempts considering two key categories: “Energy Efficiency” and “Water Efficiency.” This will aid in improving sustainability within the built environment and enhance existing buildings’ operational performance, encourages more research toward green retrofitting strategies for buildings, and develop GBRSs covering other categories in Palestine. Furthermore, employing the AHP, recognized as a powerful mathematical tool for dealing with complex MCDM problems, gives the developed system credibility and entitlement to be adopted for green evaluation in Palestine.

1.6 Literature Review

1.6.1 Basic Categories for Becoming Green

According to Shan and Hwang, (2018), there are seven main evaluation criteria for the existing GBRSs, “Energy” which emerges as the most crucial one, followed by “Location”, “Interior Environment”, “Land and Outdoor Environment”, “Material”, “Water”, and “Innovation”. The study also showed that the majority of the currently used GBRSs rated and certified GBs utilize a four-level hierarchy scoring system or higher.

1.6.1.1 Energy Efficiency

According to Dutil et al., (2011) Energy Efficiency is “using less energy without compromising the performance of the building.” Smart GB practices allow for the development of eco-friendly and resource-efficient structures. Only using a large-scale solar energy panel on the pavilion’s roof promotes resource and energy-saving. Solar energy would save 4.3 million tons of CO_2 if one million apartments used it, the estimate of removing 850,000 vehicles from the street (Hua, 2010). Wind energy is a similar technique to generate green power, requiring a considerable initial cost but yielding massive long-term savings. Each megawatt-hour of wind energy produced helps minimize one ton of GGE produced by coal or diesel generators (Jiang & Rahimi-eichi, 2009).

Improving buildings’ energy efficiency can be achieved by applying passive and/or active techniques. Active design integrates heating and cooling systems, air conditioning systems (HVAC), ventilation, hot water generation, lighting, and other services technologies (Rameshwar et al., 2019). Passive design enhance energy efficiency through building envelopes and layouts that are integrated into the building structure (Chen et al., 2015). The building envelope is what separates a building's indoor and external environments. This crucial part of any building consists of several components such as walls, façade, foundations, roofs, thermal insulation, exterior shading devices, etc. It is the key element in determining the quality and control of the interior atmosphere, regardless of changing exterior weather (Sadineni et al., 2011).

Enhancing the building envelope performance is achieved by the understanding material properties of the envelope elements, such as their thermal resistance, insulation, heat gain coefficient, and air infiltration (Jadhav et al., n.d.). Also, building materials affect operating energy as they interact with the buildings' thermal transfer. Adopting appropriate materials can save energy and reduce pollution and GGE. For instance, using high-performance materials for insulation can minimize total operational energy due to their ability to conserve heating and cooling power and limit the heat flow rate. Several materials can work as insulators, such as foam, mineral wool, and fiberglass (Hammad et al., 2021).

Researchers are looking into innovations for thermal control, such as self-shading envelopes. The use of a computer simulation tool called SustArc to create a solar collect envelope (SCE) nomogram was presented. Self-shading envelopes are designed using the SCE method, as the summer sun is blocked, but the winter sun is allowed to interiors (Sadineni et al., 2011). Furthermore, (Omrany et al., 2016) discussed various types of energy-efficient walls, such as Trombe walls, Double Skin Walls, Autoclaved Aerated Concrete Walls, and Green Walls, and their possibilities for increasing building thermal performance and minimizing energy usage.

Windows are accountable for a large proportion of overall building energy loss. Air leakage is one of the major causes of energy loss from regular windows, particularly in older and improperly installed fenestration devices. Poor airtightness could account for 40 percent of heat loss from building fabric based on the temperature variation between interior and exterior. Even in moderate climates, related heat losses and air leakage accounted for about 20 percent of overall energy loss from a window (Cuce, 2017).

Another method of controlling the amount of solar radiation that enters the building is to choose an appropriate glazing type, especially where there is a high need for heating and cooling. Several research has recently presented successful strategies for improving window energy performance by utilizing various types of glazing such as vacuum glazing, aerogel glazing, prismatic glazing, and smart glazing (Omrany, 2016).

1.6.1.2 Water Efficiency

Structures in the USA consume about 38 billion gallons of water each day. Buildings not only use a lot of water, but they also utilize it inefficiently (Howe, n.d.). A regular urinal, for example, consumes one or more gallons per flush, while a typical toilet consumes roughly 3.5 gallons per flush. On the other hand, ultra-low water urinals use only 0.125 gallons of water per flush, waterless urinals don’t use any, and High-efficiency toilets utilize only 1.2 to 1.6 gallons of water per flush (Howe, n.d.). Water efficiency is related to water usage and water waste reduction. Water waste or excessive use causes additional water to be drawn from freshwater supplies. As a result, water-saving technologies have been developed to conserve potable and non-potable water. Water-efficient solutions in buildings include water-saving fittings and fixtures, rainwater collecting, and grey water recycling and reuse (On et al., 2016).

Friedman, (2012) introduces practical solutions for water efficiency strategies and technologies. For instance, highly efficient showers, toilets, and faucets may use water half as much as ordinary types. Showers use less water than baths, based on their showers’ length, pressure, and flow rate. A shower uses 5 to 10 gallons of water every minute, whereas a full bath uses 30.5 gallons every minute. A wide variety of water-efficient showerheads exist in the markets designed to deliver flows that are potentially even more satisfactory than those provided by traditional fixtures using only 2 gallons per minute or less.

Several studies investigated the opportunities to enhance water efficiency in existing buildings. Liu and Ping, (2012) highlighted the factors that influence buildings’ water consumption as shown in Table 1. Liu and Ping, (2012) discussed the water-saving retrofitting solutions for existing buildings, such as water-saving appliances and equipment, the reuse of recycled water, and collecting and use of rainfall. Effective irrigation system is another method to enhance water efficiency. Overwatering can be avoided by adding rain or soil moisture sensors. A rain sensor detects rain for a fixed amount of time. They are less expensive than soil sensors, smaller, and quicker to install. Soil moisture sensors, which are more difficult to install, can detect exact moisture at the root system level and save water (Sheth, 2017).

Table 1

Analysis of the factors that influence buildings' water consumption

Influence	Contents	Details
The external environment	Geographical environment	Longitude, latitude, altitude
	Climate environment	Temperature, humidity, rainfall
Building design	Building function	Residential buildings, public buildings, commercial buildings
	Building shape	Shape, area, number of layers
	Building landscape	Area
Water supply and drainage system	Water supply and drainage facilities	Domestic water, irrigation water
	Water-saving measures	Reuse of recycled water and rainwater
	Water supply and drainage management	Management level, the application of intelligent control system
Human dimensions	Life habit	
	Other factors	Cultural qualitied, energy-saving awareness, income

Note: (Liu & Ping, 2012).

1.6.2 Review of Global and Local GBRSs

Various studies reviewed and compared existing GBRSs from different aspects. At this point, this research compares and investigates the common and distinct elements between six chosen GBRSs based on "Energy Efficiency" and "Water Efficiency" criteria. The selected GBRSs are global rating systems BREEAM, LEED, Green Globes, and Green Star, which were considered due to their predominance in the green certification systems of twelve nations included in the World Green Building Council (Remizov et al., 2021) (Say et al., 2008). Also, according to (Marchi et al., 2021), BREEAM, LEED, and Green Star are among the most diffused GBRSs. For the purpose of the study, local GBRSs like Estidama and the Palestinian GB Guidelines were also selected.

1.6.2.1 BREEAM

The Building Research Establishment Environmental Assessment Method (BREEAM), created in the UK in 1990, is one of the earliest recognized evaluation tool. It establishes benchmarks for buildings' environmental performance during the planning, constructing, and operating phases. Nearly 550,000 structures in 70 different countries have been evaluated by BREEAM (Remizov et al., 2021). The assessment scheme can evaluate a completely new building, an extension to an existing building, a combination of newly constructed and retrofit sections of an existing building, which may be a big mixed-use building, or building fit-out at the design or post-construction phase (Lee, 2013).

Version 1 for offices was revised first in 1993, and the second revision was conducted in 1998. BREEAM 2004 for non-domestic buildings covers a variety of buildings, such as commercial and industrial buildings, retail stores, schools, etc. It is the most well-known scheme and has accounted for between 15 and 20 percent of the UK market for new office buildings (Lee & Burnett, 2008). The BREEAM's latest version for existing buildings, non-domestic buildings, is BREEAM in Use version 6.0 which was released in May 2020.

The assessment method includes defining measurable criteria for sustainable building performance across multiple categories, including energy and water consumption, occupant health and well-being, pollution, transport, materials, waste, ecology, and management operations. Credits achievement in the mentioned categories determines points awarded, and the number of points earned in each section is multiplied by an environmental weighting factor to represent the related significance of each section. The sum of the weighted scores is translated into a scale of six stars, 1 for "Acceptable" and up to 6 stars for "Outstanding" (AbdelAzim et al., 2017). When Canada, New Zealand, Norway, Singapore, and Hong Kong, formed similar schemes, BREEAM was also used as a reference model (Lee & Burnett, 2008).

1.6.2.2 LEED

The LEED (Leadership in Energy and Environmental Design) is the most widely used GBRS and is recognized as a symbol of sustainability achievement, available for virtually building project types, from New Construction (NC) to interior fit-outs and Operation & Maintenance. LEED provides project teams a framework can apply to create healthy, highly efficient, and cost-saving green buildings (Amiri et al., 2019).

The LEED Version 2.0 was released in 2000 based on adjustments made during the pilot period. Since then, LEED has evolved to encompass more types of buildings and has continued to change to meet market demands. The LEED New Construction (NC) version released in February 2010, covers various building types, including offices, high-rise residences, government buildings, recreational facilities, manufacturing plants, and laboratories (Lee, 2013). In 2019, the latest version of LEED for NC was released, while the LEED version for Existing Buildings: Operations & Maintenance V4.1 was released in 2018.

The LEED evaluation system encompasses six categories, including sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation (Wu et al., 2016). These categories are generated from the EPA's tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) categories and consist of several prerequisite requirements and credits with distinct values. Prerequisites are essential requirements, while credits are optional requirements that serve as a strategy for the project to earn more points toward a LEED certification. First, the project must achieve all prerequisites, and a certain minimum number of points must be earned. There are 100 base points and an additional 10 points in the certification (Choi et al., 2015).

1.6.2.3 Green Globes

In 2000, Canada introduced the Green Globes rating system based on the structure of the BREEAM rating system (Ahmed et al., 2018), and it was introduced to the USA in 2004 by the Green Building Initiative (GBI) (Vierra et al., 2018). The American National Standard Institute has certified the Green Globes as a standards developer even though it is not affiliated with any particular nation (Say et al., 2008). For the building evaluation process, seven criteria are considered: Energy, Water, Site, Emissions, Resources, Indoor Environment, and Project/Environmental Management (Ahmed et al., 2018). Green Globes can be used to rate commercial or multifamily buildings, both new and existing buildings (Vierra et al., 2018).

A self-reported online evaluation survey must be completed to apply for a Green Globes certification, which is required at different points during the design and construction phase. A Green Globes Assessor will visit the site to confirm the assertions made in the survey during the construction documents phase and after the completion (Vierra et al., 2018). The Green Globes are divided into the following scoring categories: One Globe (35-54%), two Globes (55-69%), three Globes (70-84%), and four Globes (85-100%) (Remizov et al., 2021). Green Globes NC 2021 is the latest version for new construction, while Green Globes EB 2021 is the latest version for existing buildings.

1.6.2.4 Green Star

Green Star is a voluntary environmental assessment system for buildings launched in 2003 by the Green Building Council of Australia (GBCA). The system covers a wide range of sustainable challenges, occupant productivity, health, and cost reductions (Nguyen & Altan, 2011). The following categories are included in the Green Star system: energy, transport, management, indoor environmental quality, water, materials, emissions and innovation, and land use and ecology. There are five levels of certification, "One star" for Minimum Practice, "Two stars" for Average Practice, "Three stars" for Good Practice, "Four stars" for Best Practice, Five stars for Australian Excellence, and "Six stars" for World Leadership (Amiri et al., 2019).

Green Star tools were initially created for the four different stages of commercial office building development, including design, construction, fit-out, and existing buildings. Similar assessment tools for other building types are available, such as public buildings, schools, hospitals, commercial malls, office buildings, and healthcare facilities. Green Star assessment tools are not just used by market leaders or associated with official certification. The rating tools can still be used by projects that don’t fulfill certification requirements to track and enhance their environmental performance. However, these initiatives cannot claim a Green Star certification publicly (Bondareva, 2007). The latest Green Star NC version was released in 2019, while the Green Star’s latest version for existing buildings (V2.1) was released in November 2017.

1.6.2.5 ESTIDAMA

In 2010 Abu Dhabi Urban Planning Council (UPC) created the Estidama evaluating system (Awadh, 2017). Estidama is an Arabic word that means sustainability. This evaluation system is the first of its kind in the Middle East (Salim et al., 2018). Estidama is developed mainly by integrating LEED and BREEAM standards while adapting the system to the special local demands and environment of Abu Dhabi (Awadh, 2017). The designed framework assesses the sustainability of the built environment while considering four pillars: the environmental, social, economic, and cultural pillars. The rating system part of the Estidama initiative is called the Pearl Rating System (PRS). Three different versions of PRS are customized for buildings, communities, and villas, which cover all stages of construction, from design to operation (Ramani & Garc, 2021).

Seven elements form the PRS: Natural Systems, Integrated Development Process, Livable Buildings, Communities, Villas and Spaces, Precious Water, Resourceful Energy, Stewarding Materials, and Innovating Practice (Ramani & Garc, 2021). The PRS credits are divided into mandatory and optional categories. Every project filing for a PRS certification must meet the prerequisite credits. The PRS level that the project team is pursuing determines the number of points needed for the project (AbdelAzim et al., 2017). There are five certification levels available of PRS for buildings: if a project achieves only prerequisite earns "1 Pearl", adding 60 points earns "2 Pearl", adding 85 points earns "3 Pearl", adding 115 points earns "4 Pearl", and "5 Pearl" for adding 140 points (Awadh, 2017).

1.6.2.6 Palestinian GB Guidelines

Palestine Engineers Association established the Palestine Higher Green Building Council (PHGBC) in 2010. Following the Union’s vision and plans to solve the problems challenging the Palestinian society in the context of limited water and energy sources, and the high costs of the operational process of building, it was decided to initiate a guideline for GBs in Palestine. These GB Guidelines were generalized to Palestinian buildings and facilities in line with international standards for GB, taking into account the specificity of the climatic, geographical, and topographic conditions of the region (PHGBC, 2013). The scoring process for a GB is divided into six main axes (as shown in Table 2). Also, there are some mandatory requirements in all fields related to GBs. These requirements are necessary for the GB evaluation process but not accounted for as weighted points (as shown in Table 3).

Table 2

GBs evaluating scoring system according to the Palestinian GB Guidelines

Domain	Scores	Percentage
Site Sustainability	30	15%
Energy Efficiency	60	30%
Water Use Efficiency	50	25%
Indoor Environmental quality	30	15%
Materials and Resources	20	10%
Innovations and Buildings Integration Design	10	5%
Total	200	100%

Note: (PHGBC, 2013).

Table 3

Mandatory requirements in all fields adopted by the Palestinian GB Guidelines of GBs

No.	Scoring	Requirements	Field
1	Required	Prevention of pollution resulting from building and construction activities	Site sustainability
2	Required	Rationalizing and reducing water consumption	water usage efficiency
3	Required	Planning for all building energy systems Reach the minimum energy consumption Planning of building cooling systems	Energy optimization and management
4	Required	Collection and storage of recyclable and reusable materials	Resources
5	Required	Minimum indoor air quality performance Environmental control and limitation of smoking effects,	Indoor environment quality

Note: (PHGBC, 2013).

The GB Guideline of Palestine presents four classifications of GBs: Diamond (level ****, equal or more than 160 points), Gold (Level ***, 140-159 points), silver (level **, 120-139 points), Bronze (level *, 100-119 points). Finally, before assessing the building on an operational and maintenance basis, it must be occupied for a minimum of twelve months to provide accurate data on water and electricity consumption through this period. Also, the building must be committed to safety standards recognized locally and globally (Badawy et al., 2020).

1.6.2 Analytical Hierarchical Process (AHP)

Saaty (1980) created a powerful and effective method for managing qualitative and quantitative multi-criteria aspects in decision-making, called the Analytical Hierarchy Process (AHP) (Taherdoost, 2020). AHP is one of the most extensively utilized multiple criteria decision-making techniques by decision-makers and academics (Russo & Camanho, 2015). This technique considers various options and alternatives in performing sensitivity analysis on the subsequent measures and criteria (Delcev et al., 2014). AHP utilizes pairwise comparison to assign weights to criteria and prioritize alternatives systematically. AHP presents a method for calibrating the numeric scale for quantitative and qualitative performance measurement. The score goes from 1/9 for 'least valued than', 1 for 'equal', and 9 for 'more important than' (Vaidya & Kumar, 2006). AHP analyzes a problem hierarchically, progressing from a goal to criteria, sub-criteria, and alternatives. The hierarchy gives professionals a broad overview of the context's complicated linkages and aids them in determining if elements along the same level are similar. The weights of the elements are then calculated by comparing them pairwise on nine different level scales (Liu et al., 2020).

AHP is broadly adopted in construction project evaluation, such as developing a decision-support system that incorporates the relative preferences of the owner and architect among multiple key criteria, or evaluating building material suppliers while taking into account a large number of subjective and complex considerations (Maceika et al., 2021). Moreover, Lazar and Chithra, (2020) review and analyze the literature published on Building Sustainability Assessment Systems created using several MCDM techniques, including AHP, Fuzzy AHP, Analytic Network Process, Triangular Fuzzy Number, Simple Additive Weighing, and others. According to the study, the majority of research papers use expert surveys or interviews and the Delphi process in selecting the criteria while using AHP to determine criteria weight.

AHP has proven to be highly efficient in developing green rating systems in the literature. (Hazem et al., 2020) developed a new GBRS for existing buildings in Egypt. A novel checklist for existing buildings was structured and consisted of seven main criteria; the AHP was adopted for the weighing process. Ali and Al Nsairat, (2009) proposed a green building assessment tool computer-based program that fits the Jordanian region regarding environmental, social, and economic perspectives. The AHP approach was used to weight the assessment indicators chosen through a questionnaire addressed to sustainable development experts. (Kamaruzzaman et al., 2018) developed a sustainability assessment scheme for building refurbishment in Malaysia. The AHP approach also was used to rank the assessment themes and define the preferences of the study's participating stakeholders. Also, F. S. Said and Harputlugil, (2019) examines the key measures and sub-criteria to be considered in the establishment of a green building certification system for Turkey. The study used the AHP approach and employed the Expert choice 11.5 program. Finally, Alyami et al. (2015) present a customized and adjusted weighting scheme that prioritizes environmental assessment method criteria for Saudi Arabia through the AHP using the Expert Choice program.

Chapter Two

Research Methodology

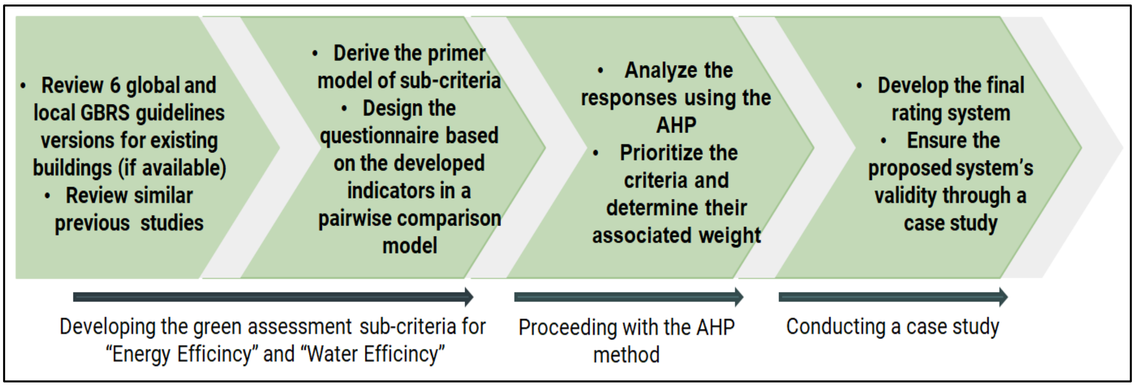
2.1 Study design

This research adopted the quantitative approach by conducting a pairwise-comparison-based questionnaire filled through semi-structured interviews and after applying the AHP approach to responses. The questionnaire was developed based on the most significant indicators required to evaluate the 'greenness' of existing buildings. A comparative study of four global and two local GBRSs was conducted to develop these indicators or sub-criteria for the Energy and Water criterion. The questionnaire was addressed to university experts, professionals, decision-makers, and engineers who work in the green construction sector and the GB council in Palestine. Then, the AHP approach was performed based on the filled questionnaire using the "Expert Choice 11" program. This step is crucial to prioritize and determine the scores and weight assigned to the criteria and the related indicators. A similar method was also adopted by AbdelAzim et al. (2017), the study developed a criteria-based energy efficiency rating system for existing buildings, and suggested that the approach can be used for other green building criterion in other developing countries.

After developing the primer system, a hypothetical case study in Palestine was created and evaluated to ensure the system validity and applicability. The selected case study is Aqqaba Green School in Tubas/Palestine, a simulation model of the Aqqaba School before it was retrofitted as a green building and the actual model of the school after retrofitting were created using DesignBuilder and EnergyPlus 9.3 software. The hypothetical case study was evaluated by two systems: the developed system in this research and the LEED (O+M). Results from both systems were compared to determine how each rating system's scores are influenced by environmental factors. Figure 1 summarizes the methodological procedure.

Figure 1

Methodology design to develop a GBRS for existing buildings in Palestine using the AHP



2.2 Comparative Analysis of the Selected GBRSs

The purpose of this section is to conclude the most significant sub-criteria or indicators required to fulfill the goal of the "Energy" and "Water" criterion. This can be achieved by analyzing each GBRS perspective on each criterion associated with their goal, value, and the weight and credit of the sub-categories. After, the main themes shared among these GBRSs are defined to build a map by matching each indicator to the related theme.

For the research objectives, only the GBRS version for existing buildings is considered in the comparison for the "Energy Efficiency" and "Water Efficiency" criteria, except for the Estidama PRS and the Palestinian GB Guidelines, which the new construction versions were considered since their versions for existing buildings have not been released yet. Appendix A shows the selected GBRSs, the version used, and the certification levels for each system.

2.3 Energy Theme Analysis

Appendix B summarizes the key sub-criteria\indicators of the "Energy" criterion for the selected GBRSs, including their target, weight, and credits according to their significance to the GBRS. Also, each indicator was defined as a mandatory requirement (Prerequisite) or optional requirement (Credits). Since these indicators serve the purpose of the "Energy" criterion (directly or indirectly), they were chosen regardless of whether they are classified under the "Energy" criteria of the GBRS or other categories. The strategy for choosing these criteria is carefully examining their intent or value. For instance, "Green Lease" is classified under the "Management" Criteria in BREEAM and Green

Star and intends to support the use of lease agreements that offer incentives for owners and renters to consider implementing energy, water, and waste-efficient systems along with other sustainable principles (BREEAM, 2020)(GBCSA, 2014). This indicator supports the “Energy” criterion practices in the built environment. Another example is “Daylight” which is classified under the “Indoor Environment Quality” in Green Star and the Palestinian GB Guidelines, and under “Health and Wellbeing” in BREEAM intends to enhance the users’ access to natural lighting to minimize the demand for artificial lighting and save energy (BREEAM, 2020) (GBCSA, 2014) (PHGBC, 2013). “Environmental Purchasing” which is classified under “Material” in Green Globe, Green Star, and LEED intends to develop policies for green purchasing including energy efficient equipment (Green Globe, 2012)(GBCSA, 2014)(LEED, 2018). The number of indicators assigned for the “Energy” criteria ranges from (2 by Green star to 18 by BREEAM). While deciding the adequate number of indicators for the “Energy” criteria is challenging, still assigning only 2 indicators is insufficient. The actual number of Energy-related indicators ranges from (6 by LEED to 22 by Green Globe) according to Appendix B.

The importance of the “Energy” criteria differs according to the specific environmental and economic conditions of each region where the GBRS was established. For instance, LEED gives the highest weight for “Energy” of 35%, while ESTIDAMA gives the least of 10%, this may be the case because ESTIDAMA was established in Abu Dhabi, a desert region, so focuses more on water issues. However, deciding the actual weight of the “Energy” criteria is complicated as each GBRS defines the sub-categories and their credits differently. For instance, while “Monitoring and Metering Energy Use” is classified under the “Energy” criteria in BREEAM and ESTIDAMA, it was classified under “Management” in Green Star. Similarly, “Reduction of nightlight pollution” was classified under “Pollution” in BREEAM and under “Site Sustainability” in the Palestinian GB Guidelines. In order to seek the actual weight assigned by the GBRS for the “Energy” criteria, the sum of available credits for the listed sub-categories in Appendix B is calculated and divided by the total credit points. It is noticed that the highest Gross Weight (GW) resulted from Green Star (40% of total weight) while ESTIDAMA still has the least weight (10% of total weight), All other systems assign GW (27% to 38%) of their total weight.

While the weighing process of the GBRSs is different, the goal of the "Energy" criterion is analogous among the selected GBRSs: To reduce the building's negative impact on the environment by achieving energy use reduction and switching to renewable energy sources. According to (Shan & Hwang, 2018) The "Energy" category in most GBRSs primarily considers energy consumption reduction, energy monitoring & reporting, energy-efficient systems, equipment, and appliances, as well as the utilization of renewable energy. (AbdelAzim et al., 2017) developed a criteria-based energy efficiency rating system for existing buildings, the study conducted a comparative analysis of six GBRSs for the "Energy" category and concluded four shared themes: "Environmental impact", "Energy sources and conservation", "Benchmarking and measurement", and "The Energy use policy and management". (Mahmoud et al., 2019) proposed a global sustainability rating tool for existing buildings, the study identifies the sustainability assessment attributes and their related indicators, for the "Energy" category four indicators were concluded: Energy Performance, Energy Management, Energy Efficient System, and Energy Efficient Equipment.

This study concluded four main "Energy" themes shared by the selected GBRSs:

- *Energy Use Efficient System:* This includes adopting energy conservation strategies to achieve significant reductions in energy consumption through retrofitting the building's envelopes, the thermal insulation and glazing of the existing building, improvement of hot-water boilers and other installed appliances, such as HVAC systems and lighting, introducing environmentally-friendly energy-generation installations, and the reduction of heat losses in local heat distribution systems, including the introduction of automation and control (Chwieduk, 2003).
- *Renewable Energy Source Integration:* Encourage on-site renewable energy integration to limit the environmental impacts of fossil fuel use of buildings through the operational phase and to reduce the energy demand and consumption for lighting, heating, cooling, electricity, etc. The proper application of renewable energy supplies includes solar sustainability systems, solar energy, wind energy, geothermal energy, biomass and biogas, electric and heat generation systems, and fuel cell (Ghaffarianhoseini et al., 2013).

- *Limiting The Environmental Impact:* Reduce the environmental impact of the building by implementing policies and practices that focus on energy usage during the building's operational phase. These impacts include resource depletion, greenhouse gas emissions, global warming, and climate change (Dutil et al., 2011).
- *Energy Management:* Achieve increasing energy performance levels over the required standard's baseline while ensuring long-term accountability for the building energy consumption (Dutil et al., 2011). Also, achieve continuous development of the building energy system through monitoring, metering, reporting, and maintenance.

By matching each indicator to the related theme, Appendix D illustrates the emphasis on each theme by the selected GBRSs. While all themes are significant to achieve Energy Efficiency, *Energy Management* has the highest emphasis of 39.3%, which is justified as the management practices are crucial to achieving a significant reduction in energy consumption, and adjusting the energy-efficient strategies to the specific case. *Renewable Energy Sources Integration* has the lowest emphasis of 10.7% as achieving the reduction in energy consumption during the operational phase of the building is more significant than finding alternative energy sources.

2.4 Water Theme Analysis

Appendix C lists the main sub-categories\indicators of the "Water" criterion for the selected GBRSs, including their target, weight, and credits according to their significance to the GBRS. Also, each indicator was defined as Prerequisite or Credit. Similarly, in regard to the "Energy" criteria, these indicators were selected regardless of whether they fall under the "Water" criteria of the GBRS or other categories since they assist the "Water" criterion's objectives (directly or indirectly). For instance, "Minimizing Watercourse Pollution" which is classified under the "Pollution" criteria in BREEAM aims to minimize the hazard of contaminated surface runoff and/or grease from cooking facilities entering drainage systems contaminating natural watercourses (BREEAM, 2020). This intent complies with the "Water" goal and supports water quality practices. Another example is "Rainwater Management" which is classified under "Site Sustainability " in LEED and Palestinian GB Guidelines, and under "Emissions" in Green Star, aims to establish site-related strategies that reduce pollution and site deterioration, and encourage the process of evaporate, collect, and utilize water onsite from 25% of the impervious surfaces and roof area for the 95th percentile rainfall event to minimize runoff volume and enhance water quality (LEED V4.1, 2018) (GBCSA, 2014) (PHGBC, 2013).

The number of indicators assigned for the “Water” criteria ranges from (1 by Green Star to 10 by BREEAM). Similarly, in regard to the “Energy” criterion assigning only 1 indicator is insufficient to fulfill the criterion target. The actual number of Water-related indicators ranges from (4 by LEED to 19 by BREEAM) according to Appendix C. The importance of the “Water” criteria differs according to the specific environmental and economic conditions of each region where the GBRS was established. For instance, the Palestinian GB Guidelines gives the highest weight to the “Water” criteria of 25%, as Palestine suffers from political implications, which resulted in a lack of control over the limited water resources. Computing the GW of the “Water” criterion for the GBRS provides more insight into the significance of the “Water” criteria to the system and the distinctive arrangement and weighting method used by the GBRS. The Palestinian GB Guidelines still give the highest weight (GW=27%) of total weight while the other GBRSs GW ranges from (18% to 22%) of their total weight.

The selected GBRSs share a common goal for the “Water” criteria: To conserve water resources by achieving a significant reduction in potable water usage and encouraging water reuse and recycling while preventing water sources pollution and maintaining water quality. According to Waidyasekara and Silva (2013), the “Water” criteria in all GBRSs purpose is to reduce or eliminate the usage of potable water in landscaping and irrigation, water recycling, and HVAC water efficiency. It also encourages the collection of rainfall, the use of grey water, and water condensation. The main themes of the “Water” creation relate to alternate water sources, water quality, water conservation performance, water cycling, and water-efficient appliance usage (Shan & Hwang, 2018).

This study concluded four main “Water” themes shared by the selected GBRSs:

- *Water Use Performance:* Achieve rising levels of water efficiency through the reduction of water consumption as well as the reduction of water wastage. This includes high-efficiency replacements for the existing plumbing fixtures and the application of water-saving technologies such as bidets, composting toilets, dry urinals, two-sectioned water closets, self-closing or electronic faucets, dual plumping systems, and low-flow fixtures and fittings (Das et al., 2015)(Sheth, 2017).

- *Water Use Management:* Encourage water auditing by tracking residents' water use of their appliances, identifying the main use zones, installing sub-meters, and monitoring these water-using zones. Create guidelines and policies that will aid residents in understanding where and how most water is consumed. In addition, enhance the current water system, for instance, by installing sensors for irrigation control, and through ongoing maintenance (Sheth, 2017).
- *Water Recycling and Reuse:* Encourage the establishment of rainfall harvesting and grey water recycling and reuse system. Rainwater is collected mainly from rooftops, while grey water is household drained wastewater except for the kitchen sink and bathroom wastewater because of their high organic matter content (Das et al., 2015). The treated rainwater is used for laundry, toilet flushing, heating, cooling, and other purposes. Recycled grey water can also be used for toilet flushing, green roof irrigation, and cooling tower make-up water (Sheth, 2017).
- *Water Quality:* Includes water practices that ensure the potable water distributed to building occupants is of sufficient quality and complies with the water quality standards outlined for various applications (Waidyasekara & Silva, 2013). These practices include the installation of treatment systems for Legionella control, the removal of "dead ends," the lining or replacement of existing unlined iron or cement pipes, the modifications to the maintenance and management of water storage facilities, and the installation of booster chlorination (Rhoads et al., 2015).

Appendix D illustrates the emphasis on each theme by the GBRSs for the "Water" criterion. ***Water Use Management*** has the highest emphasis of 39.5%, which is justified as the management practices are crucial to reduce water consumption and waste water for the green retrofitted building.

2.5 The Primer System

Following the review of the selected GBRSs, the sub-criteria for each criterion was developed while taking into account Palestine's unique environmental, cultural, and economic factors, such as the country's status as a developing country, its poor economy, its rapid population growth, its severe political implications, its moderate climate (hot, dry in summer and cold, rainy in winter) and the fact that GB and green retrofit are still relatively new and uncommon in the region. Achieving a significant reduction in energy and water use is the main goal for any GBRS; in this case, it ought to design a system demanding a *Prerequisite* in each category to guarantee the desired performance of the building: *Energy Performance: Achieving at Least a 10% Reduction over the Baseline* for the “Energy” criterion, and *Water Performance: Achieving at Least a 10% Reduction Over the Baseline* for the “Water” criterion. Similar to the Palestinian GB guidelines, most GBRSs-NC versions demand only a 5% reduction in energy and water consumption. This percentage is acceptable, considering that GB concepts are applied in each stage of the building’s construction from design to operation. In contrast, retrofitting an existing building considering GB concepts requires significant investments in the building’s existing structure, which demands a high return on investment, so the prerequisite reduction percentage set for energy and water consumption was 10%.

The Prerequisite is a mandatory requirement that must be fulfilled first for the building to be certified and offer no points. It’s not an indicator; it is rather a measure to insure the efficiency of the applied criteria to enhance the green performance of the existing building. The baseline defined here is the Energy\Water use of the existing building before applying any retrofit strategies through at least a year of occupying the building. The remaining criteria are considered credits in which the project can earn points by fulfilling them. The next phase is determining the appropriate weights and scores for the criterion and the credits criteria using the AHP approach. The following are the developed criteria:

Energy Efficiency:

- (Pre.) Energy Performance: Achieving at Least a 10% Reduction Over the Baseline
- (Credit) Retrofitting the Building’s HVAC System
- (Credit) Retrofitting the Building’s Lighting systems
- (Credit) Renewable Energy Sources: Electric and Heat Generation
- (Credit) Energy Efficient Appliances and Equipment
- (Credit) Retrofitting the Building’s Fabric: Thermal insulation/Building’s Insulation and Reducing Air Infiltration/Windows/Shading System

- (Credit) Automation and Smart Buildings Strategies
- (Credit) Energy Management Practices: Reporting/ Monitoring/ Maintaining/ Metering and Sub-Metering

Water Efficiency:

- (Pre.) Water Performance: Achieving at Least a 10% Reduction Over the Baseline
- (Credit) Water Use Management Practices: Reporting/ Monitoring/ Maintaining/ Metering and Sub-metering
- (Credit) Water Efficient Fixtures
- (Credit) Water Efficient Appliances
- (Credit) Rain Water Harvesting System
- (Credit) Water Recycling and Reuse
- (Credit) Irrigation and Landscaping Practices

2.6 Questionnaire Design

The questionnaire's English version is shown in Appendix E, and the Arabic version, which was used for data collection as Arabic is the mother language in Palestine, is shown in Appendix F. The AHP questionnaire was designed in four sections. The first section asks for the participant information, the other sections consist of pairwise comparison matrices of the significant criteria and sub-criteria for the green evaluation of existing buildings. The second section compares criteria for "Energy Efficiency" in a pairwise comparison matrix, and the third section compares criteria for "Water Efficiency". The Last section compares the criterion (Energy Efficiency, and Water Efficiency). Three linguistic values were used to represent the importance of the criteria compared: More Significant, Same Significance, and Less Significant.

For a specific matrix of order n (the number of elements to compare), the required number of judgments is given by Equation 1 (Saaty, 1987). The required no. of pairwise comparison matrices is 1 matrix for the criterion, 21 matrices for the Energy criteria, and 15 matrices for the Water criteria.

$$n(n - 1)/2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The experts who participated in the questionnaire decided on the significance of one criterion versus the other taking into consideration different factors, the feasibility and applicability of the criteria to retrofit existing buildings in Palestine, economical factors, and efficiency to achieve sustainable impacts for the retrofitted building. Moreover, it was clarified to the experts that the criteria were designed for a building, not a neighborhood or a cluster of buildings. Also, all criteria were analyzed in the context of Palestinian culture and environment.

The procedure of filling out the questionnaire involved interviews with the experts: personally and through Zoom meetings. This procedure ensures the consistency of the answers, promotes expert commentary, and enriches the study through discussion. Experts chosen from various sectors included engineers, academics, and decision-makers, who all share the required knowledge and expertise in sustainable development and green buildings. The number of experts invited to participate was 22. The number of experts involved in the study was acceptable, considering that green retrofit, improving sustainability within the built environment, and enhancing the existing building's performance following the GB standards are yet new subjects for Palestine. The AHP approach does not require a large sample size because this could include "cold-called" respondents who have a strong tendency to provide random answers, leading to a high level of inconsistency. Moreover, when focused on a specific subject, AHP can be used with a small expert number and needs the pertinent specialists only to provide their insightful analysis of an empirical study (Elshafei et al., 2022) (Rodi et al., 2022). For instance, (F. S. Said & Harputlugil, 2019) identify the most crucial criteria and standards that should be considered while creating a green building rating system in Turkey. The AHP was utilized to weigh the proposed criteria, and nine experts participated in the study. Rodi et al. (2022) investigates the GB aspects that significantly influenced rental depreciation for conventional structures in Malaysia, and prioritizes these aspects through the AHP method using a sample size of ten experts. The experts' information related to their professional field, age, educational level, career level, and knowledge level of sustainability and GBs are all summarized in Appendix G.

2.7 The Analytical Hierarchy Process

The Analytic Hierarchy Process (AHP) is one of the most widely used approaches for decision-making. AHP created under the Multi-Criteria Decision Making (MCDM), is mainly composed of strategies that are appropriate for rating significant management issues. Prioritizing the selection criteria and separating them into more and less essential categories are the main goals of the approach. Additionally, AHP is a straightforward method that focuses on pair-wise comparisons and is appropriate for assessing both qualitative and quantitative design (Aziz et al., 2016). The AHP's main operations include building hierarchies, analyzing priorities, and testing consistency. Decision-makers then need to break down certain judgment problems with a variety of criteria into their elements with relevant characteristics organized at a variety of hierarchical levels. Following that, the decision-makers pair-wise compare each cluster at the same stage based on their expertise and knowledge (Elshafei et al., 2022).

The AHP approach was used in this study to analyze the filled questionnaire by experts. The AHP will assign weights to the criteria and the related sub-criteria which represent their priority and significance to the developed system. The process of AHP was conducted as follows:

First: Building a hierarchical structure (Kamaruzzaman et al., 2018). This requires breaking down objectives and elements of the defined problem into a hierarchical model. For the study purpose, the hierarchical model consists of three levels as shown in Appendix H, top level (Focus level) includes the goal: of developing a weighting system for green assessment criteria. The second level includes the criterion level which is further divided into the related indicators\sub-criteria in the third level.

Second: Constructing pairwise comparison matrices. Pairwise comparisons are essential to the AHP's procedure. To create a pairwise comparison matrix, each element in a higher level is utilized to evaluate the elements in the level directly below in relation to it (Saaty, 1987) (Hussain et al., 2015). Each entry in the judgmental matrix (Equation 2) (A) was built by comparing the row element A_i with the column element $\boldsymbol{A_j}$ (Kamaruzzaman et al., 2018):

$$\boldsymbol{A = (a_{ij})(i, j = 1, 2, \ldots, the\ number\ of\ criteria)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The filled questionnaire data were used to construct the required matrices by converting the linguistic value into quantitative value (1: “same importance”, 1/3: “less important”, and 3: “more important”. This utilized scale is based on Saaty’s proposed fundamental scale; it was shortened to just three levels of judgment for simplicity of response (AbdelAzim et al., 2017).

Third: Deriving the priority vector. The priority vector is generated by normalizing the matrix’s main eigenvector, which through the relative weight of indicators is determined (Braunschweig, 2001). This is referred to as the local derived scale before weighting by its parent criterion. It is known as the global derived scale after weighting (Saaty, 1987). The matrices were normalized by dividing each element in the pairwise comparison matrix by the calculated sum of the values in each column (Hazem et al., 2020), and after, averaging across rows to determine the matrix’s principle eigenvector vector (Braunschweig, 2001).

Fourth: Estimating consistency ratio. Consistency verification is regarded as one of the AHP’s best advantages. The AHP approach makes use of a consistency ratio (CR) to make sure that the outcomes from various participants are consistent with one another and a linear mathematical model for straightforward interpretation (Said & Harputlugil, 2019). The pairwise comparisons should be reviewed and modified by decision-makers if it is discovered that the consistency ratio exceeds the limit. Pairwise analyses are performed and demonstrated to be consistent at every level (Elshafei et al., 2022). According to Saaty (1987) CR must not exceeds 0.10, or else decisions need to be reevaluated. The CR is calculated through Equation 3 (Kamaruzzaman et al., 2018).

$$\boldsymbol{CR = \frac{Consistency\ Index\ (CI)}{Random\ Index\ (RI)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where, CI is given by Equation 4 as:

$$\boldsymbol{CI = \frac{\lambda_{max} - n}{n-1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where:

n: No. of criteria considered

RI: Factor that depends on n. It is often calculated using tables provided by different AHP literature. Table 4 shows a look-up for (RI) values based on the matrix order n (AbdelAzim et al., 2017).

λ_{max} : The average eigenvalue of the judgment matrix, which can be computed following the steps proposed by (Hazem et al., 2020):

1. The first column values of the matrix were multiplied by the first item priority; this step is repeated to the remaining columns.
2. The summation of values across rows was calculated to define a "Weighted Sum" vector then the elements of the vector were divided by the relative priority of each criterion, which called "Sum\Weight".
3. The average of the resulting values of Sum\Weight was estimated and termed as $\boldsymbol{\lambda_{max}}$.

Fifth: Aggregating the experts' judgment. All participant responses were aggregated using the geometric mean (GM) which represents their collective opinion (Hazem et al., 2020). AHP uses a variety of approaches to aggregate group decisions. According to Xu, (2000), the weighted geometric mean is the most popular and widely used approach, and it was confirmed by the study that its complex judgment matrix exhibits adequate consistency. Also, Krejčí and Stoklasa (2018) study the weighted arithmetic and weighted geometric means, two of the most commonly used aggregation methods. The study argues that the weighted geometric mean aggregation is superior to the weighted arithmetic mean aggregation for the purpose of determining global priorities of alternatives because the weighted geometric mean aggregation's ranking is independent of normalization conditions of the local priorities while the weighted arithmetic mean aggregation's ranking is dependent.

When aggregating the judgments of multiple individuals to create a single judgment for the group, the reciprocal characteristic is crucial. Judgments must be aggregated as the reciprocal of the synthesized judgments equals the syntheses of their reciprocals. It has been demonstrated that the geometric mean is the only method for doing this. Experts might prefer to incorporate only their final conclusions drawn from each own hierarchy rather than their judgments. In that situation, one adopts the geometric mean of the final results (Hussain et al., 2015). The GM was calculated through Equation 5 and the consistency test was conducted to the aggregated matrix (Hazem et al., 2020).

$$\boldsymbol{GM} = (\boldsymbol{a_1 ij} \times \boldsymbol{a_2 ij}^* \dots\dots {}^*\boldsymbol{akij})\hat{}(\boldsymbol{1/k}) \text{ ………………..……… (5)}$$

k: no. of participants

Sixth: Generating weight of criteria and sub-criteria and synthesis the results. One of the crucial principles that the AHP offers is synthesizing the priorities. To synthesize priorities from the second level down, the AHP multiplies local priorities by the priority of the related criterion in the level above and adds for each element in a level following the criteria it impacts. This determines the composite or global priority of that element, which is then used to weigh the local priorities of the elements at the level below, related one another using it as the criterion, and so on down to the bottom level (Saaty, 1987). Results of local weights are illustrated in the next section, in which Expert Choice 11 was used to analyze the responses, as recommended by Aziz et al. (2016) and Alyami et al. (2015) for easier and reliable AHP weighting. Figure 2 summarizes the proposed AHP model to prioritize the green evaluation criteria.

Table 4

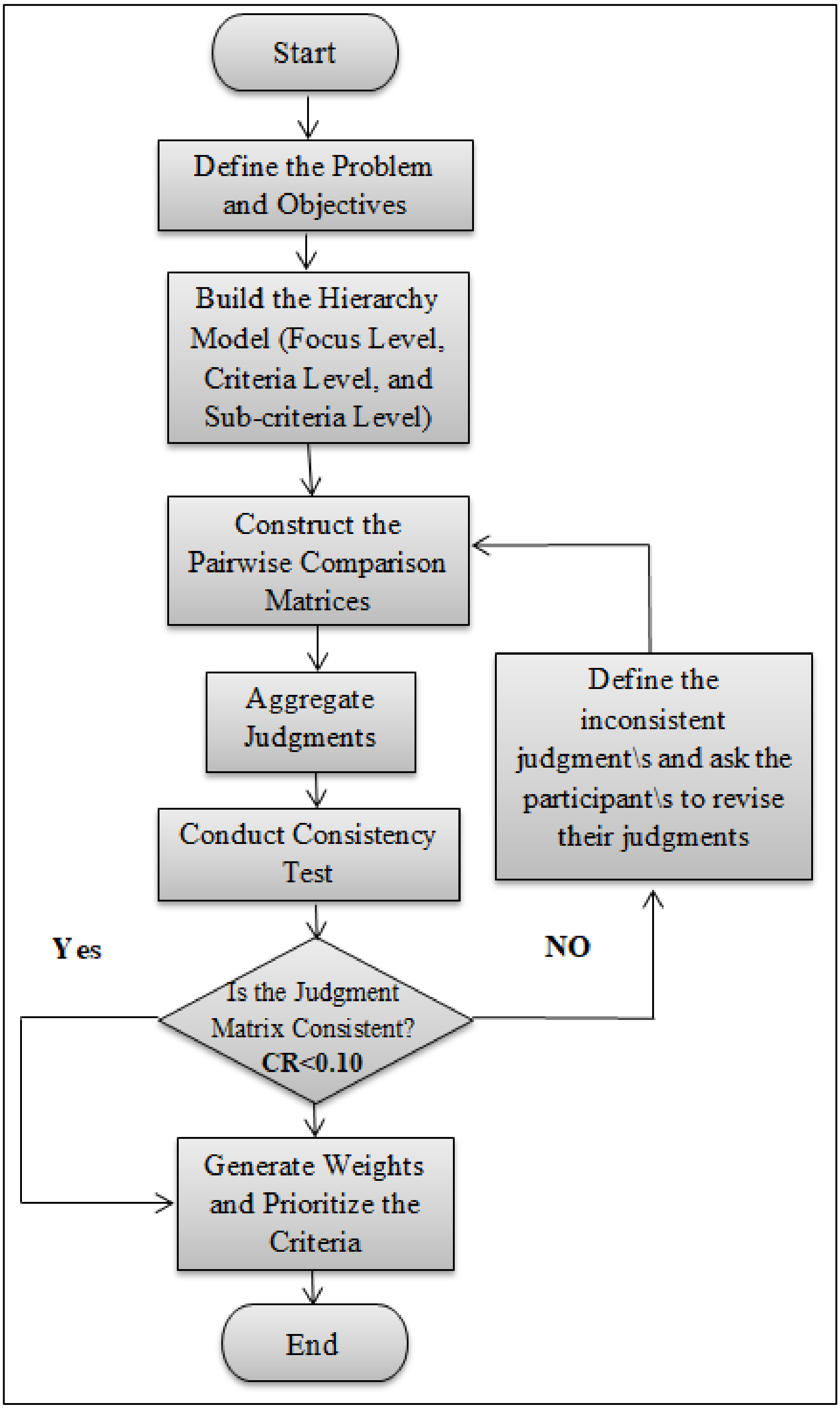
$\boldsymbol{RI}$ Values for matrix order ($\boldsymbol{n}$)

Random Index (RI) look-up from matrix order (*n*)										
n	3	4	5	6	7	8	9	10	11	12
R1	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48

Note: (AbdelAzim et al., 2017).

Figure 2

The proposed AHP approach to prioritize the green evaluation criteria for existing buildings in Palestine



Chapter Three

Results and Discussions

3.1 Overview

This chapter is divided into two main sections; the first section presents the main results of conducting the AHP approach to analyze the responses using the Expert Choice 11 program to generate weights and points for the primer model elements. This includes the aggregated matrices of the 22 participants' judgments for all levels of the hierarchy model shown in Appendix H, which were generated using the Expert Choice software. Also, the results of the consistency test are clarified for each matrix, and finally, the weight of the criterion and sub-criteria are presented. In the second section, the study's main findings are discussed and justified, and similar previous studies' results are presented.

3.2 Results

3.2.1 Criterion Weights Results

The following matrix presented in Figure 3 is the aggregated matrix for the participants' judgment for comparing the "Energy Efficiency" and the "Water Efficiency" at the same level (Criterion Level). The consistency test resulted in 0.001 (< 0.1) which is acceptable, this means the participant's judgments should not be revised. The results of the weights and the prioritization of the criteria are presented in Figure 4. According to Figure 4, the Energy criterion resulted in the highest weight of nearly (0.60), while the Water criterion yields a weight of (0.40).

Figure 3

The aggregated matrix for the Energy and Water Efficiency criterion comparison (generated from Expert Choice 11)

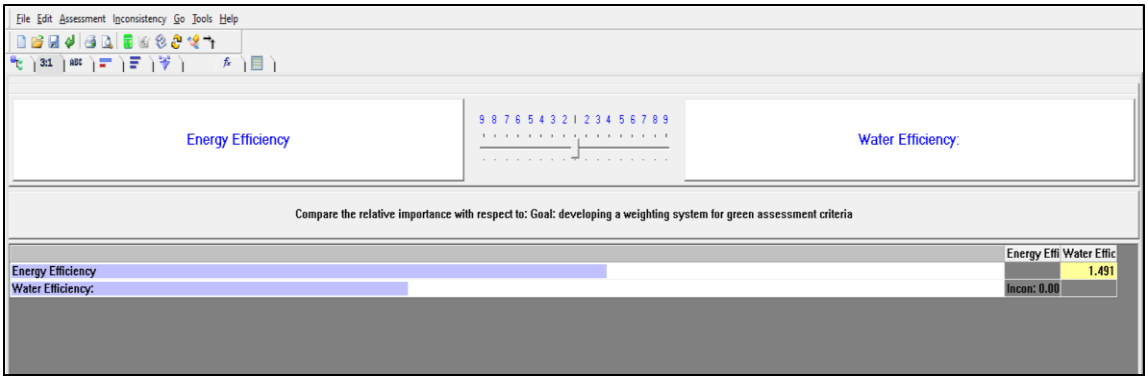
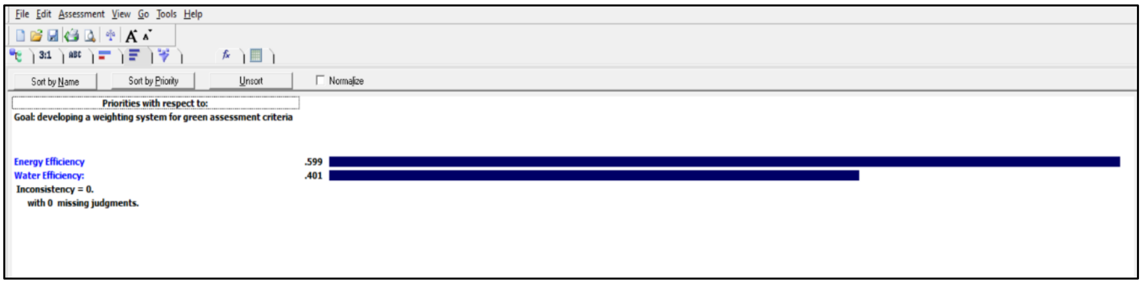


Figure 4

The prioritization for the Energy and Water Efficiency criterion (generated from Expert Choice 11)



3.2.2 The Energy Criteria Weights Results

Figure 5 presents the aggregated matrix for the participants' judgment for comparing the Energy Efficiency indicators at the same level (Sub-criteria Level). The consistency test resulted in 0.01 (< 0.1) which is acceptable, this means the participants' judgments should not be revised. The results of the weights and the prioritization of the sub-criteria are presented in Figure 6. According to Figure 6, "Retrofitting the Building's Fabric: Thermal insulation/Building's Insulation and Reducing Air Infiltration/Windows/Shading System" resulted in the highest weight of (0.254), while "Automation and Smart Buildings Strategies" resulted in the lowest weight of (0.094). "Retrofitting the Building's HVAC System" weight is (0.152), "Renewable Energy Sources: Electric and Heat Generation" weight is (0.142), "Energy Efficient Appliances and Equipment" weight is (0.127), "Retrofitting the Building's Lighting systems" weight is (0.120), and "Energy Management Practices: Reporting/Monitoring/Maintaining/Metering and Sub-Metering" weight is (0.11).

Figure 5

The aggregated matrix for the Energy Efficiency indicators comparison (generated from Expert Choice 11)

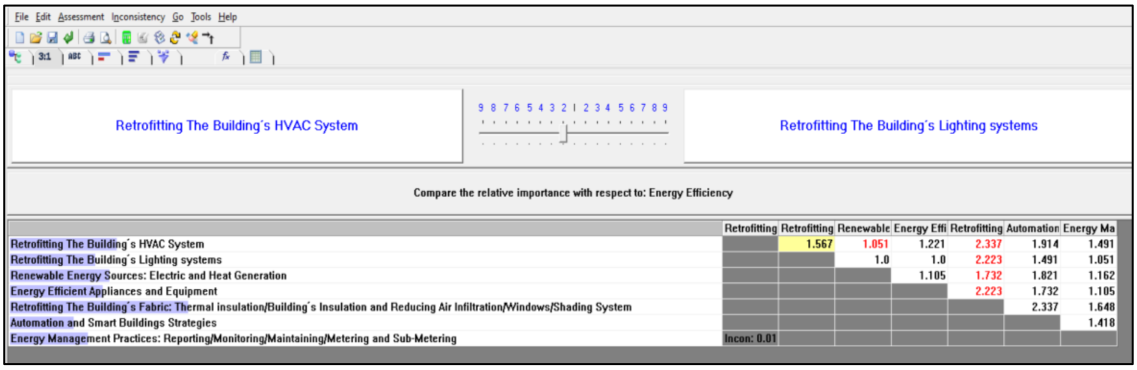
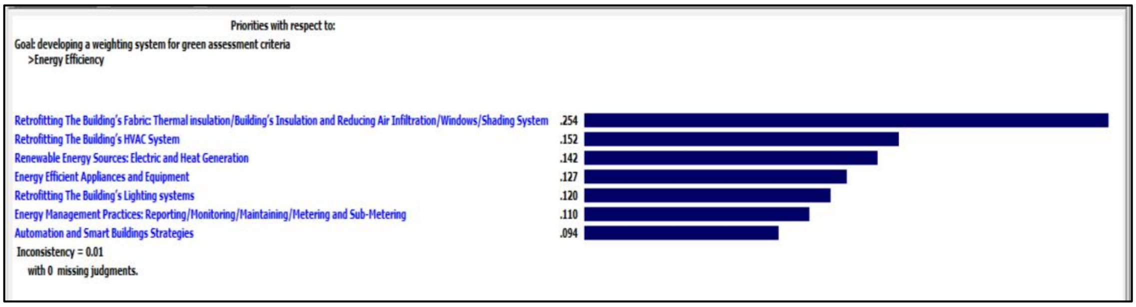


Figure 6

The prioritization for the Energy Efficiency indicators comparison (generated from Expert Choice 11)



3.2.3 The Water Criteria Weights Results

Figure 7 presents the aggregated matrix for the participants' judgment for comparing the Water Efficiency indicators at the same level (Sub-criteria Level). The consistency test resulted in 0.01 (< 0.1) which is acceptable, this means the participants' judgments should not be revised. Figure 8 summarizes the results of the weights and the prioritization of the sub-criteria. According to Figure 8, "Water Efficient Fixtures" resulted in the highest weight of (0.213), while "Irrigation and Landscaping Practices" resulted in the lowest weight of (0.131). "Rain Water Harvesting System" weight is (0.183), "Water Efficient Appliances" weight is (0.171), "Water Recycling and Reuse" weight is (0.159), and "Water Use Management Practices: Reporting/Monitoring/Maintaining/Metering and Sub-metering" weight is (0.143).

Figure 7

The aggregated matrix for the Water Efficiency indicators comparison (generated from Expert Choice 11)

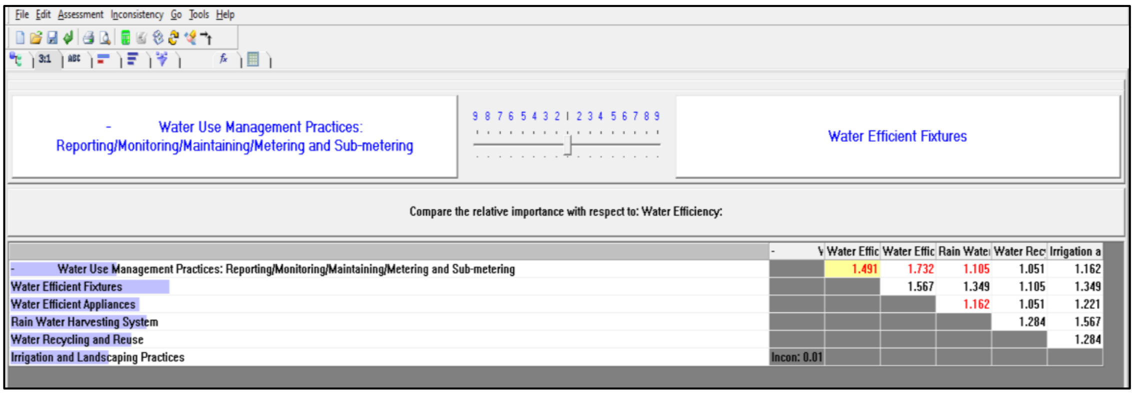
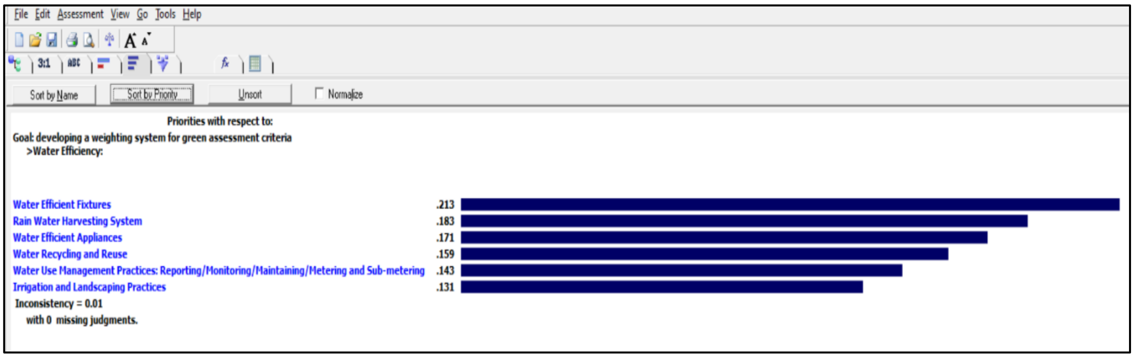


Figure 8

The prioritization for the Water Efficiency indicators comparison (generated from Expert Choice 11)



3.2.4 The Proposed GBRS for Existing Buildings

Table 5 introduces the proposed GBRS for existing buildings in Palestine (The Palestinian Energy and Water Efficiency based GBRS-EX). To determine the Scores\Points of Credits criteria weights are rounded into integer numbers. Total credits earned for a project are estimated using Equation 6 for the fulfilled criteria listed in Table 6 if the building first achieved the prerequisites in both categories.

Table 5

The proposed Green Rating System for Existing Buildings in Palestine Using The Analytical Hierarchy Process AHP regarding Energy Efficiency and Water Efficiency criteria

The Proposed Green Rating System for Existing Buildings in Palestine (The Palestinian Energy and Water Efficiency based GBRS-EX)			
Weight	Energy Efficiency 60%	Points	
Prerequisite	Energy Performance: Achieving at Least a 10% Reduction Over The Baseline	-	-
Credit	Retrofitting The Building's Fabric: Thermal insulation/Building's Insulation and Reducing Air Infiltration/Windows/Shading System	0.254	25
Credit	Retrofitting The Building's HVAC System	0.152	16
Credit	Renewable Energy Sources: Electric and Heat Generation	0.142	14
Credit	Energy Efficient Appliances and Equipment	0.127	13
Credit	Retrofitting The Building's Lighting systems	0.120	12
Credit	Energy Management Practices: Reporting/ Monitoring/ Maintaining/Metering and Sub-Metering	0.110	11
Credit	Automation and Smart Buildings Strategies	0.094	9
Weight	Water Efficiency 40%	Points	
Prerequisite	Water Performance: Achieving at Least a 10% Reduction Over The Baseline	-	-
Credit	Water Efficient Fixtures	0.213	22
Credit	Rain Water Harvesting System	0.183	18
Credit	Water Efficient Appliances	0.171	17
Credit	Water Recycling and Reuse	0.159	16
Credit	Water Use Management Practices: Reporting/ Monitoring/ Maintaining/ Metering and Sub-metering	0.143	14
Credit	Irrigation and Landscaping Practices	0.131	13

Note: Total Available points: 100.

$$\textit{Total Earned Credits} = (\textbf{total achieved points in ``Energy Efficiency'' category} \times \mathbf{60}\%) + (\textbf{total achieved points in ``Water Efficiency'' category} \times \mathbf{40}\%) \quad (6)$$

A four-level classification system is proposed to rate projects by The Palestinian GBRS-EX. The Palestinian GBs Guidelines classification system was customized to fit the proposed rating system. Bronze, Silver, Gold, and Diamond levels were used to award a project depending on the final achieved points as shown in Table 6. As the subject of green retrofitting is new to Palestine and to encourage green retrofit projects to be certified by The Palestinian GBRS-EX, it was decided that any building that achieved at least 30 points is considered certified (Bronze Level), compared to other GBRS that assign 40 points (LEED), 35 points (Green Globe), and 10 points (BREEAM and Green Star) for a project to be certified according to Table 6. Assigning 30 points will also guarantee that at least 2 credit criteria are fulfilled in each category.

Table 6

The Palestinian Energy and Water Efficiency based GBRS-EX Classification System

Achieved Points	Classification Level
30-45 points	Bronze
46-60 points	Silver
61-75 points	Gold
>75 points	Diamond

3.3 Discussion

3.3.1 Criterion Results Analysis

The "Energy" criterion earns the highest importance among experts in Palestine due to various reasons. While energy prices are increasing globally, the Palestinian condition is still much more complicated due to the poor economy, and the high population growth. Also, the political implications in Palestine have severe consequences on the energy sector and limited control over natural resources, such as water and energy. Generally, Israel controls the oil imports and makes the chance for free Palestinian open trade negligible; as a result 87% of the Palestinian needs of petroleum products and electricity are imported (Said, 2019) (Haj Hussein et al., 2022). Due to energy poverty, Palestinians are forced to live in a unique combination of social and environmental injustice. Energy poverty prohibits individuals from satisfying their most basic requirements because access to energy is necessary for meeting human needs for heat comfort, and sanitation. As a result, Palestinians are more exposed to environmental harm and live in ecologically vulnerable conditions and low quality housing (Hamed & Peric, 2020). In light of Palestine's situation, finding a sustainable solution for reducing energy consumption for existing buildings is a must. The "Water" criterion remains highly important to the

Palestinian expert for the same reasons described earlier. The fact that water costs less in Palestine than energy is why Water Efficiency received less importance than Energy Efficiency.

Different weighting results appear when comparing the study findings to similar research conducted in other countries. For instance, for the Energy category *Renewable Energy Sources: Electric and Heat Generation* comes in the third priority, while compared to the results of (AbdelAzim et al., 2017) study, the *Use of Renewable Energy Sources* comes in the highest priority. *Retrofitting The Building's Fabric: Thermal insulation/Building's Insulation and Reducing Air Infiltration/Windows/Shading System* comes in the highest priority for this study, while AbdelAzim et al. (2017) Building Envelope Efficiency Strategies comes in second priority. Similarly, for the Water category, Water Efficient Fixtures comes with the highest weight in this study while it comes in third compared to the result of the Hazem et al. (2020) study. Water Recycling and Reuse comes in fourth priority while *Wastewater Reuse* has the highest weight in the Hazem et al. (2020) study.

3.3.2 Energy Criteria Results Analysis

Results show that the experts give "Retrofitting The Building's Fabric: Thermal insulation/Building's Insulation and Reducing Air Infiltration/Windows/Shading System" the highest weight for the Energy Efficiency criterion. This is reasonable as building envelopes account for the majority of energy waste. Especially in Palestine, the buildings' structures are known for poor adaptability through seasons, as the interior environment is cold in winter and hot in summer. No matter how effective a building's energy system is, energy generated for heating or cooling can still be lost due to poorly insulated envelopes, unsealed window frames, or insufficient shading systems. While the building's fabric and design affect the need for interior heating or cooling, it also affects the need for lighting. Natural lighting is significant for occupant health and comfort, and lack of daylight requires the use of artificial lighting, which results in excessive energy use that imposes additional strain on the building's energy system and the environment as well as increasing electricity bills. Retrofitting the design of the building, including the position of the openings, and the glazing type, and applying passive design strategies allows the greatest daylight access to interiors. Moreover, the opening position enhances air circulation for a better natural ventilation mechanism.

Different studies examined passive strategies for improving the building's energy performance, for instance (Haj Hussein et al., 2022) evaluated the advantages of addressing U-values for potential future reductions in energy demand by analyzing building thermal performance under various scenarios emphasizing on building envelopes in Palestine. Using a modeling program (Design Builder), they compared the current situation with the proposed implementation of various scenarios, including the current Palestinian building energy code and other green building standards. The findings demonstrated that the current construction conditions—building without enforcing any energy standards or implementing the Palestinian building energy code—are far from the high-energy performance that may be attained by implementing local or worldwide green building codes. Depending on the kind of building, climate zone, and U-value, thermal insulation could reduce the energy used for heating by 83% to 43%.

"Retrofitting The Building's HVAC System" is the second priority for experts, as it is essential to achieve energy efficiency in existing buildings in Palestine. For instance, the highest pressure on the electricity system in summer is caused by the excessive use of inefficient HVAC system units. Monna et al. (2021) proposed a three-level retrofitting program for residential buildings in Palestine and used a Simulation model (Design Builder tool) to evaluate the energy savings by applying these strategies, such as changing the glazing type, installing a shading system, enhancing existing lighting system, improving thermal insulation and most importantly in the third level requirements changing existing HVAC system with high efficient system, and installing solar water heating system. Results show that incorporating these levels accounted for a 71-73 % reduction in the total energy consumed in residential buildings. This leads to the third priority for "Renewable Energy Sources: Electric and Heat Generation". According to Said, (2019), there is a lack of integration of renewable energy sources in the Palestinian building's energy system despite their availability, which increases the building's operational costs, and carbon emissions, and leads to depletion in available energy sources. Although Palestine uses solar water heaters the highest in the Middle East and Africa region, as solar water heater system is installed on 56% of residences' roof, one-third of these systems are defective.

Additionally, distribution losses (technical and non-technical) are relatively high (20–30 percent) (Monna et al., 2021). Improving the awareness of Renewable energy sources potential in Palestine is essential. Utilizing renewable energy sources can enable the Palestinian citizen to have better access to energy sources, especially for industries with high energy consumption. It can also be used to electrify remote regions that are disconnected from the power system (Juaidi et al., 2022). “Energy Efficient Appliances and Equipment” comes in fourth priority for experts. Consumers in Palestine frequently tend to choose the cheapest product available. As a result, they will have substantially higher operating costs in the future. Countries must invest much more in energy supply networks than they would otherwise if all appliances met minimum energy performance standards (Ibrik & Sulaiman, 2019). Many electrical devices, including audio and video instruments, personal computers, washing machines, elevators, refrigerators, etc., already employ energy-efficient technologies. Power converters with high efficiency and dependable controllers convert alternating current to direct current or vice versa, which can be employed to decrease energy usage (Ibrik and Mahmoud, 2005). (Ibrik and Sulaiman, 2019) investigates the possibilities for energy savings through high-efficiency equipment in several industries in Palestine. It was discovered that high-efficiency appliances, or “category A of appliances,” significantly reduced energy usage in residences and other commercial sectors. These actions reduce energy demand and consumption, and the reduced operating hours of this equipment contribute to lower energy bills. Additionally, this has improved consumer efforts to keep the environment clean. Although the initial cost of installing energy-efficient appliances may be high, consumers’ advantages in the long term are significant.

“Retrofitting The Building’s Lighting systems” comes in the fifth priority for experts, considering that most buildings already use LED lighting in Palestine. Energy Management Practices: Reporting/Monitoring/Maintaining/Metering and Sub-Metering” comes in the sixth priority, and “Automation and Smart Buildings Strategies” is the last priority. Energy management practices, such as installing metering and sub-metering for energy use zones, developing policies for purchasing energy-efficient appliances, developing maintenance plans, auditing, and preparing constant reporting, are essential for optimizing and monitoring existing energy systems and improving the energy performance of the building. Although they are highly crucial and receive high weights in global GBRSs, such practices generally receive less attention in Palestine, where the building’s owners are less aware of their potential to save energy and reduce associated bills. Expert interviews concluded that to encourage users to adopt similar strategies, it is essential to raise their awareness of related practices, establish rental policies and commissions, and offer incentives. The automation system is an integrated computerized control system that manages and monitors the mechanical and electrical components, including ventilation, lighting, electricity, fire prevention, and security. The systems gather and analyze data to provide insights or take the necessary actions to improve building efficiency and productivity (Priya & Prof, 2022). Through interviews, experts claim that automation is given the lowest priority because it will be inefficient due to excessive human interference, which will result in false inputs and missing controls.

3.3.3 Water Criteria Results Analysis

Results show that the experts give “Water Efficient Fixtures” the highest weight for the Water Efficiency criterion. This is justified as the primary waste of water in buildings is through existing high-flow fixtures and fittings, which can be replaced with low-flow fixtures and fittings, faucets with sensors, and other water-saving technologies designed to meet users water needs without wasting more water than they require. “Rain Water Harvesting System” comes in the second priority for experts, especially considering Palestine’s struggle with limited water sources. According to Thaher et al. (2020), the World Health Organization (WHO) recommends 100 liters of household consumption per capita per day (L/c.d.) as the minimum baseline to get full health and hygiene advantages. Contrarily, the West Bank’s household water supplies are only 62 L/c.d. obtainable. Even in Palestinian towns and cities with access to a water supply network, the water supply is inconsistent for most of the year, with only a few hours a day of water provided, typically in rotation, while the water supply may be cut off in remote places for days or even weeks. Rainwater collecting is crucial to increase the water supply for potable and non-potable uses in urban and rural regions, reduce flooding, decrease the load on public water systems, and climate change’s effects (Al-Batsh et al., 2019).

“Water Efficient Appliances” comes as the third priority for experts. Similarly in regard to the “Energy Efficient Appliances”, customers in Palestine tend to purchase the lowest price available product despite their environmental impact. Raising awareness of the advantages of corresponding water-efficient appliances will encourage consumers to switch to such appliances like washing machines and dish washer machines with low-water factors, which will result in less water used that can be saved for other uses.

According to experts, “Water Recycling and Reuse” should be prioritized fourth since it requires significant investments and may be non-affordable for Palestinian users. However, recycling grey water can be a long-term strategy for water conservation, especially if it is of high quality and reused properly. Grey water should be viewed as a resource rather than as waste. For instance, reusing treated gray water for irrigation can dramatically save water costs, enhance food security, and conserve drinking water for home use (Thaher et al., 2020).

It is obvious why “Water Use Management Practices: Reporting, Monitoring, Maintaining, Metering and Sub-metering” is the sixth priority since there is still a lack of knowledge about the importance of using effective management practices to conserve water in existing buildings in Palestine. The continuous monitoring of the water network metering and sub-metering for water consumption zones, continuous maintenance of pipelines and sanitation systems, leak detection and leak prevention, and conserving water quality is crucial to ensure the water efficiency for existing buildings. The experts who participated in the interviews emphasized the significance of raising awareness of management practices and their potential to enhance a building's performance and recommended adding educational sub-criteria under management practices to encourage users to adopt better water-use behavior. “Irrigation and Landscaping Practices” comes as the last priority, considering that most buildings in Palestine do not occupy a large agricultural land. This includes installing rain or moisture sensors to minimize overwatering, irrigation with treated wastewater, and planting areas with drought-tolerant agricultural varieties that use less water (Sheth, 2017).

Chapter Four

Case Study

4.1 Overview

Finding an appropriate case study to evaluate the system's validity was challenging because the concepts of green retrofitting to enhance sustainability within the built environment and improving building performance in terms of energy and water efficiency are all new in the context of Palestine. This is especially true given that the GB concept is still recent in the country. To resolve this issue, a hypothetical case study was developed that suited the particular conditions required for a building to be rated by the developed system. A school named Aqqaba Green School in Palestine, one of the first GBs in Palestine (new construction), was used and adjusted for this study purpose. A simulated model for the Aqqaba School before being a green building was developed (baseline model), potential green retrofit strategies were applied to the model, and the final retrofitted building was created using the Design Builder and the Energy Plus 9.3 software. The following sections illustrate the school information and condition before and after the retrofitting. The hypothetical case was evaluated using both the developed system "The Palestinian GBRS-EX" and the LEED (O+M), and finally results were compared.

4.2 Aqqaba Green School

The Aqqaba Green School is Palestine's first green school and has received a Gold rating from the Palestinian GB Council (see Appendix I). Aqqaba School is located in the village of Aqqaba in Tubas and experiences mild winters and hot, dry summers. The school began operations in 2016 with 156 students and a total space of 1408 square meters. In addition to having seven classrooms, two laboratories, a library, and green areas, the school uses solar energy to generate electricity, three water wells, and a gray water recycling system (Said, 2019).

Since Aqqaba School is green new construction, it was not suitable to evaluate it as it is using the developed system; as a result, a hypothetical model of the school before being green was developed and considered an existing building using the Design Builder and the Energy Plus 9.3 software (as shown in Appendix I). This model is the baseline to which the school was evaluated in reference to. Also, a conception model of the resulting school after applying different green retrofit strategies was developed (as shown in Appendix I). Table 7 summarizes the green retrofit strategies for the Energy and Water Efficiency criteria. The baseline model was designed in American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards and both models schools were equipped with solar cells of the same capacity.

Table 7

Summary of the green retrofit strategies applied to the case study

Baseline Model	Retrofitted Model
Energy Efficiency Retrofitting The Building's Fabric	
U value generated by the Design Builder software according to the ASHRAE standards for the defined zone (2B) equals 0.6 for facades and equals 0.4 for ceilings. No shading devices were used.	Enhanced U value for the building facades equals 0.4 and equals 0.3 for the ceiling by improving the insulation of the existing buildings envelopes. Vertical and horizontal louvers were designed for the southeast windows for shading.
Retrofitting The Building's HVAC systems	
Boiler Chiller HVAC Systems.	Variable Refrigerant Flow (VRF) system.
Retrofitting The Building's Lighting systems	
Fluorescent lighting T5 .	LED lighting.
Automation and Smart Buildings Strategies	
No automation strategies were used.	Classrooms and offices are installed with motion detectors sensors (occupancy sensor).
Water Efficiency Water Efficient Fixtures	
Ordinary Toilet faucets. Ordinary Kitchen faucet. Ordinary Single flush toilet. Ordinary Water drinker (manual).	Sensored toilets faucets 2 L\min. Kitchen faucet 8 L\min. Dual flush toilet 6 L\flush. Water drinker (manual)2 L\flush.
Rain Water Harvesting System	
No rain harvesting system was used.	Rain water harvesting tank was used (as shown in Appendix I).
Water Recycling and Reuse	
No grey water recycling system was used.	Grey water recycling tank was used (as shown in Appendix I).

4.3 The evaluation Process

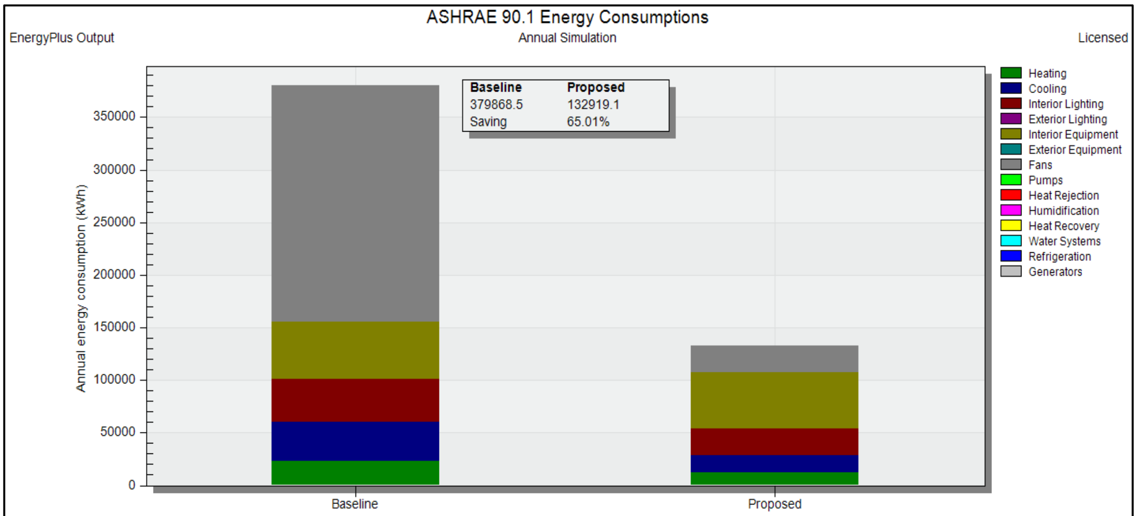
This section evaluates the case study using the developed system in this research "The Palestinian GBRS-EX" and the LEED (O+M) and compares results. This step is crucial to ensure the developed system's validity concerning the applicability of the criteria and the process of soring to award a project, moreover, to clarify why it is important for Palestine to establish its version of GBRS for existing buildings that fit the country's specific cultural, economic, and environmental conditions.

4.3.1 Evaluating The Case Study by The Developed System

The first step to evaluate the retrofitted building in terms of energy efficiency is to test the project's conformity with the Prerequisite: *Energy Performance: Achieving at Least a 10% Reduction Over The Baseline.* This can be insured by using EnergyPlus 9.3 software to estimate the expected reduction in energy consumption over a year. Figure 9 shows that the energy savings obtained by implementing the retrofit strategies are 65% (>10%), which satisfies the primary requirement for the Palestinian GBRS-EX. These strategies included the HVAC system, Lighting system, Retrofitting the building fabric, and Automation and smart building strategies. When compared to Figure 10, the energy savings obtained are only 33.5% if replacing the current HVAC system is not included to retrofit the existing building. The massive difference in the findings confirms that *Retrofitting The Building HVAC System* must receive high scores due to its significant impact on energy efficiency. The next step, for the credits criteria the case fulfilled in Energy Efficiency criterion were scored, and the total points awarded were calculated.

Figure 9

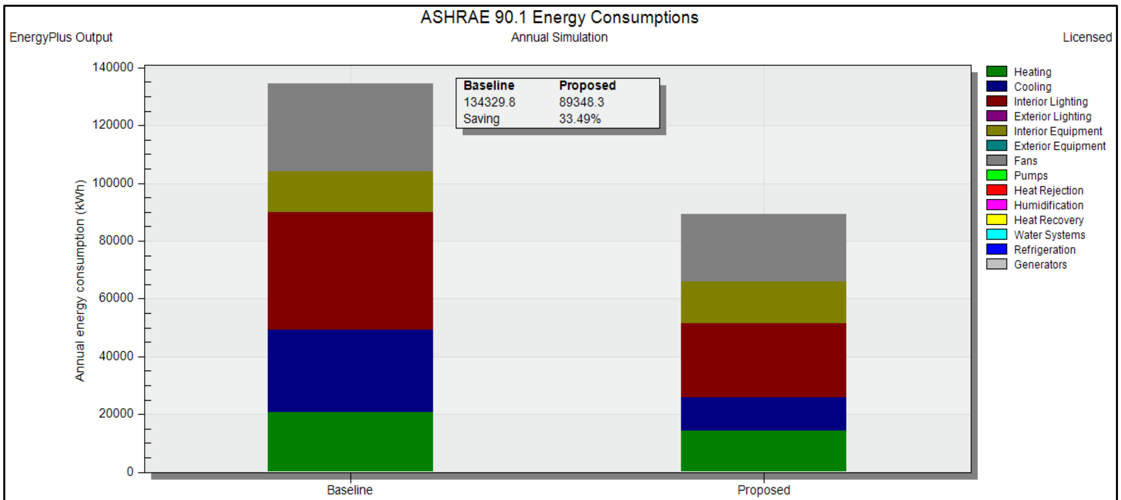
The estimated energy saving achieved for the case study by the retrofitting generated from EnergyPlus software (retrofitting the HVAC system included)



	Baseline	Proposed
Heating	23366.12	12042.17
Cooling	37136.14	16179.82
Interior Lighting	40676.86	25765.94
Exterior Lighting	0.00	0.00
Interior Equipment	53843.39	53843.39
Exterior Equipment	0.00	0.00
Fans	224846.00	25087.78

Figure 10

The estimated energy saving achieved for the case study by the retrofitting generated from EnergyPlus software (retrofitting the HVAC system is not included)



	Baseline	Proposed
Heating	20805.80	14346.47
Cooling	28391.49	11449.91
Interior Lighting	40676.86	25765.94
Exterior Lighting	0.00	0.00
Interior Equipment	14231.57	14231.57
Exterior Equipment	0.00	0.00
Fans	30224.04	23554.38

Similarly to the energy efficiency criterion, to evaluate the retrofitted building in terms of water efficiency is to test the project's conformity with the Prerequisite: *Water Performance: Achieving at Least a 10% Reduction Over the Baseline.* This can be insured by estimating the expected reduction in water consumption over a year. The baseline value for water consumption of the Aqqaba School before being green can be acquired from the water consumption of similar schools in Palestine (high school female students). The chosen schools for this purpose are included in Appendix J. Through Equation 7 and Equation 8 the average water use per student of the selected schools was calculated, and through Equation 9 the average yearly water consumption for Aqqaba School was calculated. After contacting Aqqaba School to obtain the current water bills, the data were considered as the case's water consumption following the retrofit; then finally, the reduction percentage in water use was computed using Equation 10.

$$\textbf{The School Average Water Use/Stu.} = \frac{\textbf{Yearly Water Consumption}}{\textbf{Total Students Numbers}} \ldots\ldots\ldots(7)$$

Yearly Water Consumption was computed through the school's monthly water bills

$$\textbf{Average Water Use/Stu. of The Selected Schools} = (\sum \text{ of the School Average Water Use\textbackslash Stu.}) \div \text{The Selected Schools Number} \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$$\textbf{Aqqaba School Average Yearly Water Use}$$
$$= \frac{\textbf{Average Water Use}}{\textbf{Stu.of The Selected Schools}} \times \textbf{Aqqaba School Useres Number} \ldots\ldots\ldots\ldots\ldots (9)$$
$$= 1.104147 \times 473 = 522.2617$$

$$\textbf{The Water Use Reduction Percentage} = \mathbf{1} - \frac{\textbf{Water consumption after the retrofit}}{\textbf{Water consumption before the retrofit}} \ldots\ldots\ldots(10)$$

$$= 1- (282 \div 522.2617) = 0.460041$$

The Water Use Reduction Percentage equals 46% (>10%) which satisfies the main prerequisite. The last step, for the credits criteria the case fulfilled in Water Efficiency criterion were scored, and the total points awarded for the project were calculated (as shown in Table 8.

Table 8

The case study achieved points in Energy and Water Efficiency criterion for "The Palestinian Energy and Water Efficiency based GBRS-EX"

The Palestinian Energy and Water Efficiency based GBRS-EX		
	Energy Efficiency 60%	Points
Prerequisite	Energy Performance: Achieving at Least a 10% Reduction Over The Baseline	✓
Credit	Retrofitting The Building's Fabric: Thermal insulation/ Building's Insulation and Reducing Air Infiltration/ Windows/ Shading System	25
Credit	Retrofitting The Building's HVAC System	16
Credit	Renewable Energy Sources: Electric and Heat Generation	0
Credit	Energy Efficient Appliances and Equipment	0
Credit	Retrofitting The Building's Lighting systems	12
Credit	Energy Management Practices: Reporting/ Monitoring/ Maintaining/ Metering and Sub-Metering	0
Credit	Automation and Smart Buildings Strategies	9
	Water Efficiency 40%	Points
Prerequisite	Energy Performance: Achieving at Least a 10% Reduction Over The Baseline	✓
Credit	Water Efficient Fixtures	22
Credit	Rain Water Harvesting System	18
Credit	Water Efficient Appliances	0
Credit	Water Recycling and Reuse	16
Credit	Water Use Management Practices: Reporting/ Monitoring/ Maintaining/Metering and Sub-metering	0
Credit	Irrigation and Landscaping Practices	0

$$Total\ Earned\ Credits = (\text{total achieved points in “Energy Efficiency” category } \times 60\%) + (\text{total achieved points in “Water Efficiency” category } \times 40\%) \ \ldots\ldots\ldots\ldots\ldots.(11)$$

$$= (25 + 16 + 12 + 9) \times 0.60 + (22 + 18 + 16) \times 0.40$$

$$= (62) \times 0.60 + (56) \times 0.40 = 59.6\ Points$$

According to the proposed classification system for the Palestinian GBRS-EX, the case study earns a Silver Level (46-60 points).

4.3.2 Evaluating the Case Study by the LEED (O+M)

Table 9 presents the main criteria adopted by the LEED (O+M) version V4.1 (LEED, 2018) for the Energy and Water Efficiency categories. Table 10 summarizes the evaluation process of the case study by the LEED (O+M) and the earned points by the case.

Table 9

The LEED (O+M) rating system requirements for the Energy and Water Efficiency categories

LEED (O+M) V4.1		
	Energy Efficiency	Available Points
Prerequisite	Energy Efficiency Best Management Practices: This criterion requires constant energy audit that complies with the ASHRAE preliminary energy usage analysis standards. Establish and update records of the project's operations and maintenance schedule, facilities requirements, and other relevant information for the building energy system (LEED, 2018)	-
Prerequisite	Fundamental Refrigerant Management: This criterion requires not using of CFC-based refrigerants in HVAC systems unless it has been proven that it would not be economically feasible. Reduce annual leakage to 5% or less in the project if CFC-based refrigerants are retained (LEED, 2018).	-
Prerequisite	Energy Performance: Install sub-meters permanently to measure the power and fossil fuels used by the building and equipment (LEED, 2018).	33
Credit	Enhanced Refrigerant Management: First option to not using refrigerants or using low-impact refrigerants, or other options use the calculation of refrigerant Impact (LEED, 2018).	1
Credit	Grid Harmonization: Consider building systems and equipment that make energy generation and distribution systems more efficient (LEED, 2018).	1
	Water Efficiency 15%	Available points
Prerequisite	Water Performance: LEED V4.1 requires first the project to install metering and sub-metering system to track and measure the project's potable water used through fixtures and fittings, irrigation, HVAC, bathrooms, pantries, and cooling towers (LEED, 2018).	15 6 Required

Table 10

The case study achieved points in Energy and Water Efficiency criterion for The LEED (O+M)

LEED (O+M) V4.1			
Energy Efficiency		The Evaluation Process	Earned Points
Prerequisite	Energy Efficiency Best Management Practices:	As there is no energy management activities planned in the building, the case is not fulfilling this requirement; as a result, the prerequisite is not fulfilled.	Not Achieved
Prerequisite	Fundamental Refrigerant Management:	By retrofitting existing HVAC system in the building with Variable Refrigerant Flow (VRF) system, this requirement is fulfilled	✓
Prerequisite	Energy Performance:	As no metering or sub-metering system is installed in the building to track energy consumption, the case is not fulfilling this requirement; as a result, no points can be earned in the category.	Not Achieved
Credit	Enhanced Refrigerant Management:	By using VRF-R290 refrigerant system with ODP of 0 and GWP less than 50, this requirement is satisfied	1
Credit	Grid Harmonization:	There is no Demand Response Program, Demand Response Capable Building, or Load Flexibility and Management Strategies available. The case is not fulfilling this requirement.	0
Water Efficiency 15%		The Evaluation Process	Earned Points
Prerequisite	Water Performance	As no metering or sub-metering system is installed in the building to track water use, the case is not fulfilling this requirement; as a result, no points can be earned in the category.	Not Achieved

Note. (ODP): ozone depletion potential of zero. (GWP): global warming potential

To avoid bias in the green evaluation of the hypothetical case study external experts with a LEED certification for Energy and Water Efficiency were consulted to evaluate the case, and the final scores earned in both categories were calculated as indicated in Table 10. The majority of the criteria were not met by the case study, as shown in Table 10; as a result, no points could be awarded in any of the categories because the prerequisites were not satisfied.

Chapter Five

Conclusions and Recommendations

5.1 Summary of Findings

This study employed the AHP to develop a weighting system for the proposed GBRS for existing buildings in Palestine. The resulting system called *The Palestinian Energy and Water Efficiency based GBRS-EX* consists of two criteria*: Energy Efficiency* and *Water Efficiency*. Both criteria were further subcategorized into eight indicators and seven indicators respectively. These criteria considered significant in evaluating the 'greenness' of existing buildings by reviewing six global and local GBRSs. Each category one *Prerequisite* is demanded to be fulfilled for a project to be certified by *the Palestinian GBRS-EX* while the remaining criteria are considered *Credits* for the project to earn points. Customizing the Palestinian GB Guidelines classification system proposed a four-level classification system. In order to encourage users in Palestine to adopt green retrofits in their properties—especially given that green retrofits and enhancing sustainability in the built environment are still relatively new in the country—it was approved that a project must receive at least 30 points to be certified. The significance of the system concluded in offering a roadmap to decision-makers concerning the indicators and criteria that affect the 'greenness' of existing buildings, promoting energy and water efficiency strategies within the building, also providing initiatives to pave the way for additional research on green retrofit and the development of GBRS for existing buildings that cover other categories.

5.2 Conclusion

A hypothetical case study was developed and evaluated by *the Palestinian Energy and Water based GBRS-EX* and *LEED (O+M)* to examine the validity and applicability of the developed rating system. Results show multiple factors contribute to the substantial difference between the systems' final scores. First, LEED is a global rating system primarily used in developed and advanced countries, whereas Palestine is a developing country. As a result, most of the LEED criteria do not apply to Palestine's nature. Second, GBRS are affected by the region's environmental, cultural, and economic characteristics where the GBRS was established. This ensures the necessity for developing the GBRS Palestinian version for existing buildings and encourages further research on green retrofit applications and methods in the built environment of Palestine. Finally, the evaluation process for the hypothetical case study by *The Palestinian Energy and Water Efficiency based GBRS-EX* approved the significance of the developed indicators in achieving Energy and Water Efficiency in existing buildings. For instance, the EnergyPlus software reveals that retrofitting the HVAC system in the case study contributes to almost 43% of energy saving achieved and 65% energy saving when combined with other energy retrofitting strategies, including retrofitting the building fabric, retrofitting the lighting system, and applying automation and smart buildings strategies. Also, applying water-saving retrofits, including installing water-efficient fixtures, water recycling and reuse, and rainwater harvesting system, achieved 43% savings in water consumption.

5.3 Recommendations

Main recommendations of this study are:

- To adopt the proposed system by the study to evaluate the Palestinian existing buildings in terms of Energy and Water Efficacy.
- Further research is needed to cover other categories regarding the ‘greenness’ of existing buildings in Palestine, and to develop versions concentrate on specific types of buildings.
- Offering governmental incentives like tax reductions or financing contributions to building’s owners seeking sustainable methods to reduce energy and water consumption in their properties.
- Collaboration among government and different stakeholders is required to put the developed system in operation and promote the means to apply for the certification.

5.4 Limitations

The study's limitations include the following:

- Because of the limited time allowed to complete the thesis requirements, the study concentrates only on two categories for the green evaluation of existing buildings: Energy efficiency and Water efficiency.
- The absence of an actual case study of an existing building that has been green retrofitted into an energy- or water-efficient building in Palestine since the green retrofit subject is still recent in the country.

List of Abbreviations

Abbreviations	Meaning
AHP	Analytical Hierarchy Process
ASGB	Assessment Standard for Green Buildings
BREEAM	Building Research Establishment Assessment Method United Kingdom
CASBEE	Comprehensive Assessment System for Built
CI	Consistency Index
CO_2	Carbon Dioxide
CR	Consistency Ratio
EPA	United States Environmental Protection Agency
GB	Green Buildings
GBCA	Green Building Council of Australia
GBI	Green Building Initiative
GBRS	Green Building Rating System
GGE	Greenhouse Gas Emissions
GM	Geometric Mean
GW	Gross Weight
GWP	Global Warming Potential
HVAC	Heating and Cooling Systems, Air Conditioning Systems
LCA	Life Cycle Assessment
LEED	Leader ship in Energy and Environmental Design
LEED (O+M)	LEED for Operation and Maintenance
MCDM	Multi-Criteria Decision Making
NABERS	National Australian Building Environmental Rating System
NC	New Construction
ODP	Ozone Depletion Potential
PHGBC	Palestine Higher Green Building Council
SCE	Solar Collect Envelope
SDGs	Sustainable Development Goals
The Palestinian GBRS-EX	The Palestinian Green Building Rating System for Existing Buildings
UK	United Kingdom
UN	United Nation
USA	United State of America
WHO	World Health Organization

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Appendices

Appendix A

The GBRSs version selected for the study and the classification system adopted by each system

GBRS	BREEAM UK	LEED USA	Green Globe	GREEN STAR Australia	ESTIDAMA PRS Abu Dhabi	Palestinian GB Guidelines Palestine
Version Used	BREEAM in Use V6 2020	LEED V4.1 Operations & Maintenance 2018	Green Globe for Existing Buildings V1.0 2021	Green Star-Performance 2014	The Pearl Rating System for Estidama-2016	Palestinian GB Guidelines-2013
Certification Levels	Outstanding: ≥85 Excellent: ≥70 to <85 Very Good: ≥55 to <70 Good: ≥40 to <55 Pass: ≥25 to <40 Acceptable: ≥10 to <25 Unclassified: <10	Certified: 40-49 points Silver: 50-59 points Gold: 60-79 points Platinum: 80+	One Globe (35-54%) Two Globes (55-69%) Three Globes (70-84%) Four Globes (85-100%)	10-19: One Star 20-29:Two Star 30-44: Three Star 45-59: Four Star 60-74: Five Star that recognizes/rewards 'South Africa Excellence' 75+: Six Star that recognizes/rewards 'World Leadership'	All required credits: Pearl All+50% of the optional credits: Green Pearl All+75% of the optional credits: Exemplar Pearl	Bronze: 100-119 points Silver: 120-139 Gold: 140-159 Diamond: equal or +160

Appendix B

The Energy-related indicators for the selected GBRSs and their associated credits

GBRS \ Category	Energy Category Target	Sub- Categories	Weight	Credits
	Energy	• Asset Performance		
BREEAM	“Encourages the	- Health and Wellbeing		
	reduction of energy	Hea. 01 Day lighting		4+1*
	use by recognizing	- Energy	25%	66
	building with lower	Ene.1- 9 Asset energy calculator		40
	operational energy	guidance		-
	consumption and	Ene.1 (Pre.) Building services		-
	carbon emissions	Ene.2 (Pre.) Percentage of mechanical		-
	over the lifetime of	ventilation		-
	the asset. It assesses	Ene.3 (Pre.) Fabric performance		-
	the inherent energy	Ene.4 (Pre.) Air permeability of the		-
	efficiency of the	fabric		-
	building fabric,	Ene.5 (Pre.) Cooling		-
	installed servicing	Ene.6 (Pre.) Heating		-
	systems and	Ene.7 (Pre.) Internal lighting		4*
	renewable energy	Ene.8 (Pre.) Ventilation		
	generation	Ene.9 (Pre.) Water heating		4
	capacity”	Ene.10 Demand side management		3
	(BREEAM 2020)	(DSM) capabilities for electricity		4
		Ene.11 Installed controls		1
		Ene.12 Local energy performance asset		4
	TOTAL Credit	rating		
	Points for Asset	Ene.13 Solar photovoltaic (PV) panels		4
	Performance : 238	Ene.14 Solar thermal panels		4
		Ene.15 Monitoring energy uses		2
		Ene.16 Monitoring tenanted areas	GW	70
		Ene.17 External lighting	27%	
		Ene.18 Energy efficient transport		
		systems		4
	TOTAL Credit	Total No. of Indicators: 19		58
	Points for	• Management Performance	27%	50
	Management	- Management		-
	Performance : 194	Man 05 Green lease		-
		- Energy		
		Ene.19-24 Operational energy calculator		-
		Ene.19 (Pre.) Energy consumption		4
		Ene.20 (Pre.) Carbon intensity district		4
		heating and cooling		3*
		Ene.21 (Pre.) Renewable electricity		
		generated		4
		Ene.22 Energy audit		66
		Ene.23 Energy consumption reporting	GW	
		Ene.24 Reduction of carbon emissions	30%	
		- Pollution		
		Pol 06 Reduction of nighttime light		
		pollution		
		Total No. of Indicators: 9		
LEED	Energy and	• Existing Buildings Scorecard		
	Atmosphere	- Energy and Atmosphere	35%	35
	" To reduce	EA.1 (Pre.) Energy Efficiency Best		-
	environmental and	Management Practices		

	economic harms	EA.2 (Pre.) Fundamental Refrigerant		-
	associated with	Management EA.3 (Pre.) Energy		33
	excessive energy	Performance		6.5(R)
	use by reducing			1
	greenhouse gas	EA.4 Enhanced Refrigerant Management		1
	emissions and			
	achieving higher	EA.5 Grid Harmonization		-
	levels of operating	- Materials and Resources		1
	energy	MR.1 (Pre.) Purchasing Policy	GW	36
	performance"	MR.4 Purchasing	36%	
	(LEED, 2018)	Total No. of Indicators: 7		
				34
		• Interior Scorecard	34%	-
		- Energy and Atmosphere		
	TOTAL Credit	EA.1 (Pre.) Energy Efficiency Best		-
	Points: 100	Management Practices		33
		EA.2 (Pre.) Fundamental Refrigerant		6.5(R)
		Management		1
		EA.3 (Pre.) Energy Performance		
				-
		EA.4 Enhanced Refrigerant Management		4
		- Materials and Resources		38
		MR.1 (Pre.) Purchasing Policy	GW	
		MR.4 Purchasing	38%	
		Total No. of Indicators: 6		
		- Material		
GREEN		Mat.1.1.1 Cycle Renovations		5
GLOBE		Mat.1.2.1 Environmental Purchasing		5
	-	- Indoor Environmental Quality		
		IEQ.4.1.1 Day lighting & Electrical		4
		Lighting Features		
		- Energy	31%	310
	TOTAL Credit	En.1.1 Energy Consumption		100
	Points: 1000	En.2.1Envelope		15
		En.2.2 Lighting		20
		En.2.3 Building Automation System		6
		(BAS) & Controls		
		En.2.4 Cooling Systems		15
		En.2.5 Heating Systems		15
		En.2.6 Hot Water		3
		En.2.7 Simultaneous Heating & Cooling		8
		En.2.8 Air Handling Equipment &		10
		Ventilation		2
		En.2.9 Vertical Transportation		15
		En.3.1 Energy Maintenance Program		20
		En.3.2 Energy Audits		18
		En.3.3 Commissioning		31
		En.3.4 Energy Monitoring, Policy, &		32
		Management		
		En.4.1 Renewable & Alternative Energy		
		- Environmental, Social, &		12
		Governance (ESG)		
		Management		6
		ESG.1 Environmental Management		
		System (EMS) Documentation		10
		ESG.2 Operations & Maintenance		2
		Training		
		- Resilience	GW 35%	354

		Res.1 Risk Assessment & Facility Adaptation Res.3 Building Occupant Environmental Training & Communications Total No. of Indicators: 22		
GREEN STAR	Energy “To encourage the reduction of greenhouse gas emissions associated with the use of energy in building operations.” (GBCSA, 2014) TOTAL Credit Points: 130	- Management MAN-1 Certified Buildings MAN-3 Building Management A. Building Operations Manual B. Building Users’ Guide C. Maintenance Management D. Life Cycle Maintenance MAN-4 Green Cleaning Performance A. Purchase of Green Cleaning Equipment MAN-5 Green Leasing MAN-6 Ongoing Monitoring and Metering A. Basic Monitoring Strategy for Energy B. Advanced Monitoring Strategy for Energy - Indoor Environment Quality IEQ-6 Daylight and Views - Energy ENE-1 Energy Consumption (GHGE) A. Minimum Requirements: 12 months* of historic energy consumption data for the building must be available. B. Energy Performance ENE-2 Peak Electricity Demand A. Minimum Requirement: Historical Peak Electricity Demand Data B. Peak Electricity Demand - Material MAT-1 Procurement and Purchasing - Land Use and Ecology ECO-2 Grounds-keeping Practices Total No. of Indicators: 11	20% GW 40%	1 5 1 1 1+1* 1 1 1 6 1 0.5 0.5 2 27 25 - 25+2* 2 - 2 6 3 52
ESTIDAMA PRS	Resourceful Energy “ Targeting energy conservation through energy efficiency, improved awareness, monitoring and reporting and renewable sources.” (Estidama, 2016) TOTAL Credit Points: 20	- Resourceful Energy RE.1 (Pre.) Lighting Compliance RE.2 (Pre.) Energy Monitoring & Reporting RE.3 Renewable Energy Technologies RE.4 Energy Educational Learning - Integrated Development Process IDP.R2 Sustainable Buildings IDP.R3 Commissioning Total No. of Indicators: 6	10% GW 10%	2 - - 1 1 R R 2
Palestinian GB Guidelines	Energy Efficiency Establishing general rules to	- Energy Efficiency EE.1 (Pre.) Planning for All Building Energy Systems	30%	60 - -

	enhance energy efficiency in GBs, and reduce energy consumption (PHGBC, 2013)	EE.2 (Pre.) Reach Minimum Energy Consumption		- 25
		EE.3 (Pre.) Planning of Building Cooling Systems		18
		EE.4 Optimizing Energy Efficiency - Thermal Insulation and Shading		12
		EE.5 Exploiting Renewable Energy		5
		EE.6 Using Efficient Equipment and Devices Used in Buildings		2
	TOTAL Credit Points: 200	EE.7 Smart Buildings		
		- Site Sustainability		2
		SS.7 Light Pollution Reduction		3
		- Indoor Environment Quality	GW 33%	67
		IEQ.7 Thermal Comfort		
		IEQ.8 Daylight and Glare		
		Total No. of Indicators: 10		

- (*): Exemplary Credits (Pre.): Perquisite (R): Required (GW): Gross Weight = $\frac{\text{Sum of the total available credits for the “Enrgy” criterion}}{\text{Total credits available in the rating system}}$

Appendix C

The Water-related indicators for the selected GBRSs and their associated credits

Category / GBRS	Water Category Target	Sub- Categories	Weight	Credits
	Water:	• Asset Performance		
	“Encourages sustainable	- Health and Wellbeing		
	water use throughout	Hea. 13 Drinking water provision		2
	the operation of the	- Water Efficiency	11%	38
	asset, and the associated	WAT.1 Water monitoring		6+1*
	site. This ensures the	WAT.2 Water efficient equipment:		4
	asset focuses on	toilets		4
BREEAM	identifying means of	WAT.3 Water efficient equipment:		4
	reducing potable water	urinals		
	consumption (internal	WAT.4 Water efficient equipment:		4
	and external) over the	hand washing basins		4
	lifetime of the building	WAT.5 Water efficient equipment:		4
	and minimizing losses	showers		2
	through leakage.”	WAT.6 Water efficient equipment:		4
	(BREEAM 2020)	white goods		2
		WAT.7 Leak detection system		
		WAT.8 Leak prevention		
		WAT.9 Isolation valves		4+1*
	TOTAL Credit Points	WAT.10 Reducing utility-supplied		2
	for Asset Performance :	water consumption		
	238	- Resilience		4
		Rsl. 01 Flood risk assessment	GW 18%	50
		Rsl. 02 Surface water run-off		
	TOTAL Credit Points	impact mitigation	9%	16
	for Management	- Pollution		4
	Performance : 194	Pol. 01 Minimizing watercourse		2
		pollution		4
		Total No. of Indicators: 14		6
		• Management Performance		
		- Water Efficiency		13
		WAT.11 Water consumption		4
		WAT.12 Water recycling		
		WAT.13 Water consumption		4
		reporting		2
		WAT.12 Water strategy		
		- Management		3
		Man.03 Maintenance policies and		
		procedures	GW 20%	42
		Man.05 Green lease		
		- Health and Wellbeing		
		Hea.18 Legionella risk		
		management		
		Hea.19 Drinking water		
		management		
		- Pollution		
		Pol.07 Inspection of watercourse		
		pollution prevention features		
		Total No. of Indicators: 9		
	Water Efficiency	• Existing Buildings		
	“To support water	Scorecard	15%	15
LEED	management and reduce	- Water Efficiency		15

	water consumption" (LEED, 2018)	WE.1 (Pre.) Water Performance		6 (R)
		- Sustainable Site		1
		SS.1 Rainwater Management		1
		SS.4 Site Management		
		- Materials and Resources		-
		MR.1 (Pre.) Purchasing Policy		1
		MR.4 Purchasing		
		- Indoor Environment		1
		Quality	GW 19%	19
	TOTAL Credit Points: 100	IEQ.5 Green Cleaning		
		Total No. of Indicators: 6		
			15%	15
		• Interior Scorecard		15
		- Water Efficiency		6 (R)
		WE.1 (Pre.) Water Performance		
				-
		- Materials and Resources		4
		MR.1 (Pre.) Purchasing Policy		
		MR.4 Purchasing		3
		- Indoor Environment Quality	GW 22%	22
		IEQ.5 Green Cleaning		
		Total No. of Indicators: 4		
		- Water	18.5%	185
GREEN GLOBE	-	Wat.1.1 Water Consumption		65
		Wat.2 Water Conserving Features		40
		Wat.3 Outdoor Water		30
	TOTAL Credit Points: 1000	Consumption		50
		Wat.4 Water Quality &		
		Management		5
		- Material		
		Mat.1 Cycle Renovations		1
		- Hazard Prevention		
		HP.3.3.1 Lead		4
		- Indoor Environmental Quality		
		IEQ.5.3.1 Access to Potable Water		4
		- Environmental, Social, & Governance (ESG)		
		Management		3
		ESG.1 Environmental		
		Management System (EMS)		5
		Documentation		15
		- Resilience	GW 22%	222
		Res.1 Risk Assessment & Facility Adaptation		
		- Site		
		S.1 Site Pollution		
		S.2 Site Enhancement		
		Total No. of Indicators: 12		
	Water "To recognize efficient potable water use associated with building operations thus reducing the burden on potable water supply	- Management		
		MAN.3 Building Management		5
		A. Building Operations		1
		Manual		1
		B. Building Users' Guide		1+1*
		C. Maintenance Management		1
		D. Life Cycle Maintenance		1
				1

GREEN	and wastewater	MAN.4 Green Cleaning		6
STAR	systems.”	Performance		1
		A. Purchase of Green		0.5
		Cleaning Equipment		0.5
		MAN.5 Green Leasing	9%	12
		MAN.6 Ongoing Monitoring and		12
		Metering		12+2*
		A. Basic Monitoring		
		Strategy for Water		6
	TOTAL Credit Points:	B. Advanced Monitoring		
	130	Strategy for Water		2
		- Water		3
		WAT.1 Potable Water		
		A. Potable Water		1
		Performance		0.5
		- Material		0.5
		MAT.2 Solid Waste		1.5
		Management		0.5
		- Land Use and Ecology		0.5+0.5
		ECO.1 Ecological and Site		*
		Management	GW 20%	0.5
		ECO.2 Grounds-keeping		26.5
		Practices		
		- Emissions		
		EMI.2 Legionella		
		A. Risk Management		
		B. Control of Legionella in water systems		
		EMI-3 Storm Water		
		A. Storm Water Management		
		B. Storm Water Run-off Reduction		
		C. Storm Water Quantity		
		Total No. of Indicators: 10		
	Precious Water:	- Precious Water	20%	4
	“Reducing water	PW.1 (Pre.) Water Efficiency		-
ESTIDAMA	demand and	PW.2 (Pre.) Water Monitoring &		-
PRS	encouraging efficient	Leak Detection		-
	distribution and the	PW.3 (Pre.) Storm Water		1
	reuse and recycling of	Management		1
	water.”	PW.4 Improved Water Efficiency		1
	(Estidama, 2016)	PW.5 Water Features		1
		PW.6 Improved Storm Water		
		Management		-
	TOTAL Credit Points:	PW.7 Water – Educational		-
	20	Learning		
		- Integrated Developments		-
		Process	GW 20%	4
		IDP.R2 Sustainable Buildings		
		IDP.R3 Commissioning		
		- Livable Spaces		
		LS.R6 Legionella Prevention		
		Total No. of Indicators: 10		
		- Water Efficiency	25%	50
	Water Efficiency	WE.1 (Pre.) Water Use Efficiency		-
	Establishing general			16
	rules to enhance water			

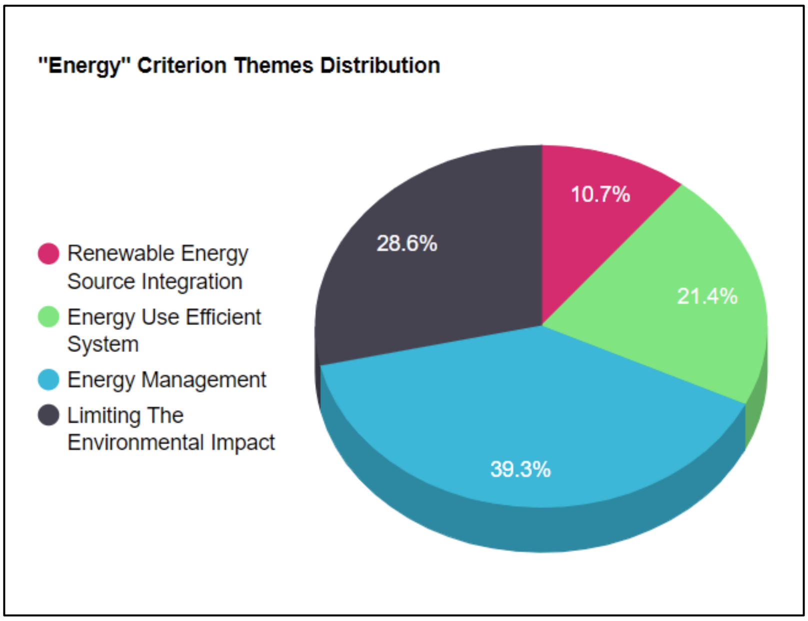
Palestinian GB Guidelines	efficiency in GBs, and reduce water consumption. (PHGBC, 2013)	WE.2 Reducing Cold Water Consumption (Water-Consuming Appliance)		16 4
		WE.3 Reducing Hot Water Generating and Consumption		8
		WE.4 Rain Water Harvesting and Re-use & Condensate Water Exploitation		6
	TOTAL Credit Points: 200	WE.5 Waste Gray Water Recycling and Re-use		4 1
		WE.6 Water System Management, Monitoring, Metering, and Control		2
		- Site Sustainability		1
		SS.9 Storm Water Design A. Use of a rainwater management system during and after storms B. Collect and treat at least 90% of rainwater C. Establishing operation and maintains plan	GW 27%	54
		Total No. of Indicators: 7		

(*): Exemplary Credits (Pre.): Perquisite (R): Required (GW) Gross Weight = $\frac{\text{Sum of the total available credits for the “Water” criterion}}{\text{Total credits available in the rating system}}$

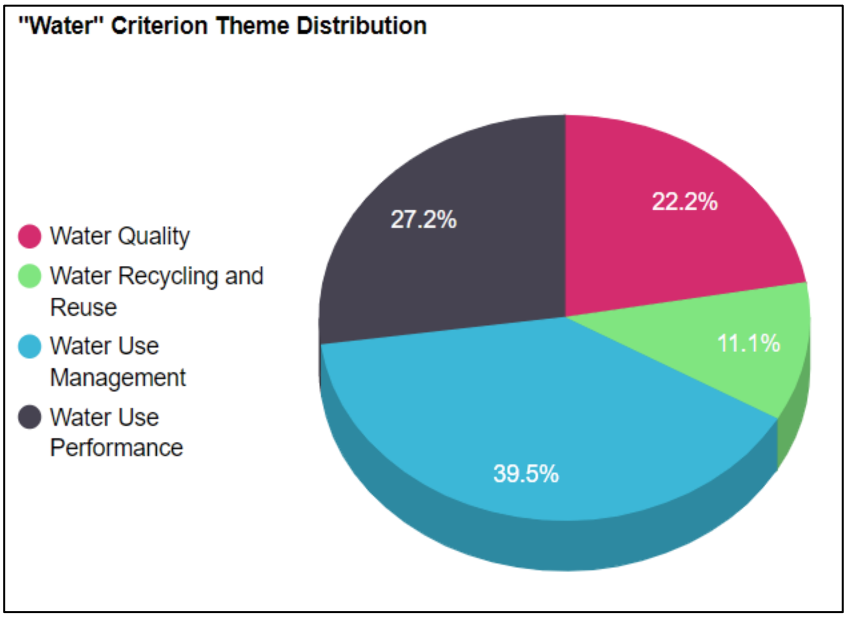
Appendix D

Distribution of the green indicators themes in both categories (Energy and Water)

Distribution of the energy themes for the selected GBRSs



Distribution of the water themes for the selected GBRSs



Appendix E

The pairwise comparison-designed questionnaire used by this study (English Version)

Developing a Green Rating System for Existing Buildings in Palestine

This survey is being conducted as part of a master's thesis project to improve the built environment's sustainability in Palestine by developing a green rating system concerning "Energy Efficiency" and "Water Efficiency" of existing buildings.
Please respond to the following: the first section of this questionnaire, which asks for the participant information, and the second section, which includes questions of pairwise comparisons of indicators for Energy and Water efficiency.
Eng. Aseel Al Qudsi - Master Student
Al Najah National University

Participants Information

Please respond to the following questions.

Name? *

Your answer

Age? *

- ◯ less than 25
- ◯ 25 - 35
- ◯ 36 - 45
- ◯ 46 - 60
- ◯ more than 60

Educational Level? *

- ◯ Bachelor Degree
- ◯ Master Degree
- ◯ PHD Degree

Professional field? *

Your answer

Career level? *

- ◯ Entry Level: Less than 3 years of experience
- ◯ Mid Career: 3–10 years of experience
- ◯ Senior Level: More than 10 years of experience

Knowledge Level of Sustainability and Green Buildings? *

- ◯ Fair
- ◯ Medium
- ◯ High

Back Next Clear form

Section 3 of 6

Energy Efficiency Rating Model

This section consists of pairwise comparison questions of the significant indicators for the criterion of "Energy Efficiency", please select the value that represents the importance of the **indicator listed in each row** compared to the **defined indicator in each question**. Your answer is crucial to define the accurate scores that will be assigned later to each indicator which represents their significant to the "Energy" criterion.

Compared to " **Retrofitting The Building's HVAC System**", please rate the importance of the following criteria: *

	More Important	Same Importance	Less Important
Retrofitting The Building's Lighting systems	○	○	○
Renewable Energy Sources: Electric and Heat Generation	○	○	○
Energy Efficient Appliances and Equipment	○	○	○
Retrofitting The Building's Fabric: Thermal insulation/Building's Insulation and Reducing Air Infiltration/Windows/Shading System	○	○	○
Automation and Smart Buildings Strategies	○	○	○
Energy Management Practices: Reporting/Monitoring/Maintaining/Metering and Sub-Metering	○	○	○

Compared to " **Retrofitting The Building's Lighting systems**", please rate the importance of the following criteria: *

	More Important	Same Importance	Less Important
Renewable Energy Sources: Electric and Heat Generation	◯	◯	◯
Energy Efficient Appliances and Equipment	◯	◯	◯
Retrofitting The Building's Fabric: Thermal insulation/Building's Insulation and Reducing Air Infiltration/Windows/Shading System	◯	◯	◯
Automation and Smart Buildings Strategies	◯	◯	◯
Energy Management Practices: Reporting/Monitoring/Maintaining/Metering and Sub-Metering	◯	◯	◯

Compared to " **Renewable Energy Sources: Electric and Heat Generation**", please rate the importance of the following criteria: *

	More Important	Same Importance	Less Important
Energy Efficient Appliances and Equipment	○	○	○
Retrofitting The Building's Fabric: Thermal insulation/Building's Insulation and Reducing Air Infiltration/Windows/Shading System	○	○	○
Automation and Smart Buildings Strategies	○	○	○
Energy Management Practices: Reporting/Monitoring/Maintaining/Metering and Sub-Metering	○	○	○

Compared to " **Energy Efficient Appliances and Equipment**", please rate the importance of the following criteria: *

	More Important	Same Imortance	Less Important
Retrofitting The Building's Fabric: Thermal insulation/Building's Insulation and Reducing Air Infiltration/Windows/Shading System	○	○	○
Automation and Smart Buildings Strategies	○	○	○
Energy Management Practices: Reporting/Monitoring/Maintaining/Metering and Sub-Metering	○	○	○

Compared to **" Retrofitting The Building's Fabric: Thermal insulation/Building's Insulation and Reducing Air Infiltration/Windows/Shading System"**, please rate the importance of the following criteria: *

	More Important	Same Importance	Less Important
Automation and Smart Buildings Strategies	○	○	○
Energy Management Practices: Reporting/Monitoring/Maintaining/Metering and Sub-Metering	○	○	○

Compared to **" Automation and Smart Buildings Strategies"**, please rate the importance of the following criteria: *

	More Important	Same Importance	Less Important
Energy Management Practices: Reporting/Monitoring/Maintaining/Metering and Sub-Metering	○	○	○

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Section 4 of 6

Water Efficiency Rating Model

Similarly to the "Energy" section, please respond to the following pairwise comparison questions of the significant indicators for the criterion of "Water Efficiency".

Compared to "**Water Use Management Practices: Reporting/Monitoring/Maintaining/Metering and Sub-metering**", please rate the importance of the following criteria: *

	More Important	Same Importance	Less Important
Water Efficient Fixtures	○	○	○
Water Efficient Appliances	○	○	○
Rain Water Harvesting System	○	○	○
Water Recycling and Reuse	○	○	○
Irrigation and Landscaping Practices	○	○	○

Compared to " **Water Efficient Fixtures**", please rate the importance of the following criteria: *

	More Important	Same Importance	Less Important
Water Efficient Appliances	○	○	○
Rain Water Harvesting System	○	○	○
Water Recycling and Reuse	○	○	○
Irrigation and Landscaping Practices	○	○	○

Compared to " **Water Efficient Appliances**", please rate the importance of the following criteria: *

	More Important	Same Importance	Less Important
Rain Water Harvesting System	○	○	○
Water Recycling and Reuse	○	○	○
Irrigation and Landscaping Practices	○	○	○

Compared to " **Rain Water Harvesting System**", please rate the importance of the following criteria: *

	More Important	Same Importance	Less Important
Water Recycling and Reuse	○	○	○
Irrigation and Landscaping Practices	○	○	○

Compared to " **Water Recycling and Reuse**", please rate the importance of the following criteria: *

	More Important	Same Importance	Less Important
Irrigation and Landscaping Practices	○	○	○

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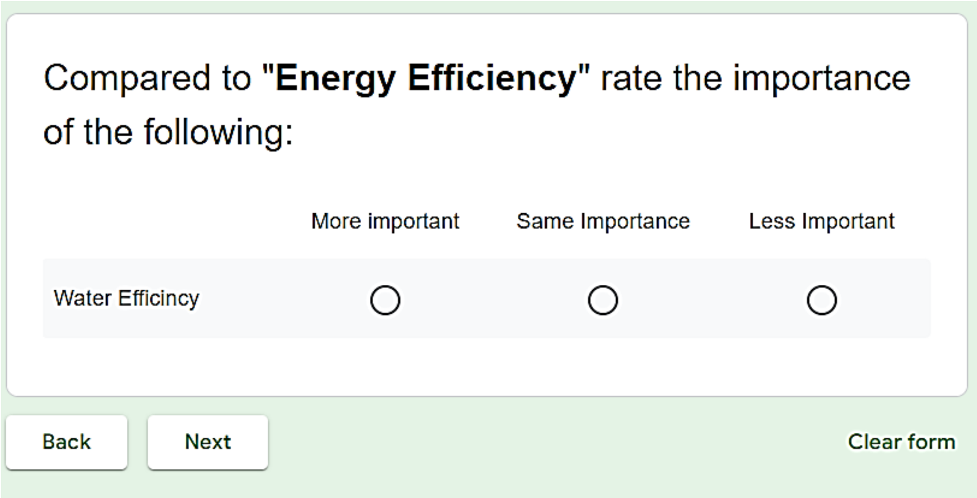

Compared to "**Energy Efficiency**" rate the importance of the following:

	More important	Same Importance	Less Important
Water Efficincy	○	○	○

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Appendix F:(الاستبيان المصمم للمقارنة الزوجية المستخدمة في هذه الدراسة (النسخة العربية

تطوير نظام تصنيف أخضر للمباني القائمة في فلسطين

Save translation

يتم إجراء هذا الاستبيان كجزء من مشروع أطروحة الماجستير يهدف لتحسين استدامة البيئة المبنية في فلسطين من خلال تطوير نظام تصنيف أخضر يختص ب "كفاءة الطاقة" و "كفاءة المياه" للمباني القائمة. تم تصميم هذا الاستبيان على قسمين , الأول مخصص لتعبئة بيانات المشاركين , و القسم الثاني يتكون من أسئلة مقارنة معايير فيما يختص بكفاءة الطاقة وكفاءة المياه يرجى الاجابة عليها

Eng. Aseel Al Qudsi - Master Student

Al Najah National University

معلومات المشاركين

الرجاء الرد على الأسئلة التالية

اسم؟ *

إجابتك

العمر؟ *

- ○ أقل من 25
- ○ 25 - 35
- ○ 36 - 45
- ○ 46 - 60
- ○ أكثر من 60

المستوى التعليمي؟ *

- درجة البكالوريوس
- درجة الماجستير
- درجة الدكتوراه

المجال المهني؟ *

إجابتك

المستوى الوظيفي؟ *

- مبتدأ: أقل من 3 سنوات خبره
- متوسط الخبرة: 3-10 سنوات من الخبرة
- المستوى المتقدم: أكثر من 10 سنوات من الخبرة

مستوى المعرفة بالاستدامة والمباني الخضراء؟ *

- مقبول
- متوسط
- ممتاز

رجوع التالي محو النموذج

نموذج تصنيف كفاءة الطاقة

يتكون هذا القسم من أسئلة المقارنة الزوجية للفئات الفرعية المهمة لمعيار "كفاءة الطاقة" ، يرجى تحديد القيمة التي تمثل أهمية المؤشر المدرج في كل صف مقارنة بالمؤشر المحدد في كل سؤال. إجابتك مهمة لتحديد النقاط التي سيتم تخصيصها لاحقًا لكل مؤشر والتي تمثل أهميتها بالنسبة لمعيار "الطاقة"

بالمقارنة مع "التعديل التحديثي لنظام التدفئة والتكييف للمبنى" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
تعديل أنظمة الإضاءه في المبنى	○	○	○
مصادر الطاقة المتجدده: توليد الطاقة الكهربائية والطاقة الحرارية	○	○	○
الأجهزة والمعدات الموفره للطاقة	○	○	○
تعديل نسيج المبنى: العزل الحراري / عزل المبنى وتقليل تسرب الهواء / النوافذ / نظام التظليل	○	○	○
استراتيجيات الأتمتة والمباني الذكية	○	○	○
ممارسات إدارة الطاقة: إعداد التقارير / المراقبة / الصيانة / العدادات الفرعية	○	○	○

بالمقارنة مع "تعديل أنظمة الإضاءة في المبنى" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
مصادر الطاقة المتجدده: توليد الطاقة الكهربائية والطاقة الحرارية	○	○	○
الأجهزة والمعدات الموفره للطاقة	○	○	○
تعديل نسيج المبنى: العزل الحراري / عزل المبنى وتقليل تسرب الهواء / النوافذ / نظام التظليل	○	○	○
استراتيجيات الأتمتة والمباني الذكية	○	○	○
ممارسات إدارة الطاقة: إعداد التقارير / المراقبة / الصيانة / العدادات الفرعية	○	○	○

بالمقارنة مع "مصادر الطاقة المتجددة: توليد الطاقة الكهربائية والطاقة الحرارية" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
الأجهزة والمعدات الموفره للطاقة	○	○	○
تعديل نسيج المبنى: العزل الحراري / عزل المبنى وتقليل تسرب الهواء / النوافذ / نظام التظليل	○	○	○
استراتيجيات الأتمتة والمباني الذكية	○	○	○
ممارسات إدارة الطاقة: إعداد التقارير / المراقبة / الصيانة / العدادات الفرعية	○	○	○

بالمقارنة مع "الأجهزة والمعدات الموفرة للطاقة" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
تعديل نسيج المبنى: العزل الحراري / عزل المبنى وتقليل تسرب الهواء / النوافذ / نظام التظليل	○	○	○
استراتيجيات الأتمتة والمباني الذكية	○	○	○
ممارسات إدارة الطاقة: إعداد التقارير / المراقبة / الصيانة / العدادات الفرعية	○	○	○

بالمقارنة مع "تعديل نسيج المبنى: العزل الحراري / عزل المبنى وتقليل تسرب الهواء / النوافذ / نظام التظليل" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
استراتيجيات الأتمتة والمباني الذكية	○	○	○
ممارسات إدارة الطاقة: إعداد التقارير / المراقبة / الصيانة / العدادات الفرعية	○	○	○

بالمقارنة مع "استراتيجيات الأتمتة والمباني الذكية" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
ممارسات إدارة الطاقة: إعداد التقارير / المراقبة / الصيانة / العدادات الفرعية	○	○	○

رجوع   التالي   محو النموذج

نموذج تصنيف كفاءة المياه

بطريقة مماثلة لقسم "الطاقة" ، يرجى الرد على أسئلة المقارنة الزوجية التالية الخاصة بالمؤشرات المهمة لمعيار "كفاءة المياه".

مقارنةً بـ "ممارسات إدارة استخدام المياه: إعداد التقارير / المراقبة / الصيانة / العدادات الفرعية" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
تركيبات موفره للمياه	○	○	○
معدات وأجهزة موفره للمياه	○	○	○
نظام تجميع مياه الأمطار	○	○	○
إعادة تدوير المياه وإعادة استخدامها	○	○	○
ممارسات الري وتنسيق الحدائق	○	○	○

مقارنةً بـ "تركيبات موفرة للمياه" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
معدات وأجهزة موفره للمياه	○	○	○
نظام تجميع مياه الأمطار	○	○	○
إعادة تدوير المياه وإعادة استخدامها	○	○	○
ممارسات الري وتنسيق الحدائق	○	○	○

مقارنةً بـ "معدات وأجهزة موفرة للمياه" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
نظام تجميع مياه الأمطار	○	○	○
إعادة تدوير المياه وإعادة استخدامها	○	○	○
ممارسات الري وتنسيق الحدائق	○	○	○

مقارنةً بـ "نظام تجميع مياه الأمطار" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
إعادة تدوير المياه وإعادة استخدامها	○	○	○
ممارسات الري وتنسيق الحدائق	○	○	○

مقارنةً بـ "إعادة تدوير المياه وإعادة استخدامها" ، يرجى تقييم أهمية المعايير التالية: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
ممارسات الري وتنسيق الحدائق	○	○	○

رجوع التالي محو النموذج

مقارنةً بـ "كفاءة الطاقة" قيم أهمية التالي: *

	اكثر اهمية	نفس الأهمية	اقل اهمية
كفاءه استخدام المياه	○	○	○

رجوع   التالي   محو النموذج

Appendix G

Data of the experts who participated in the study

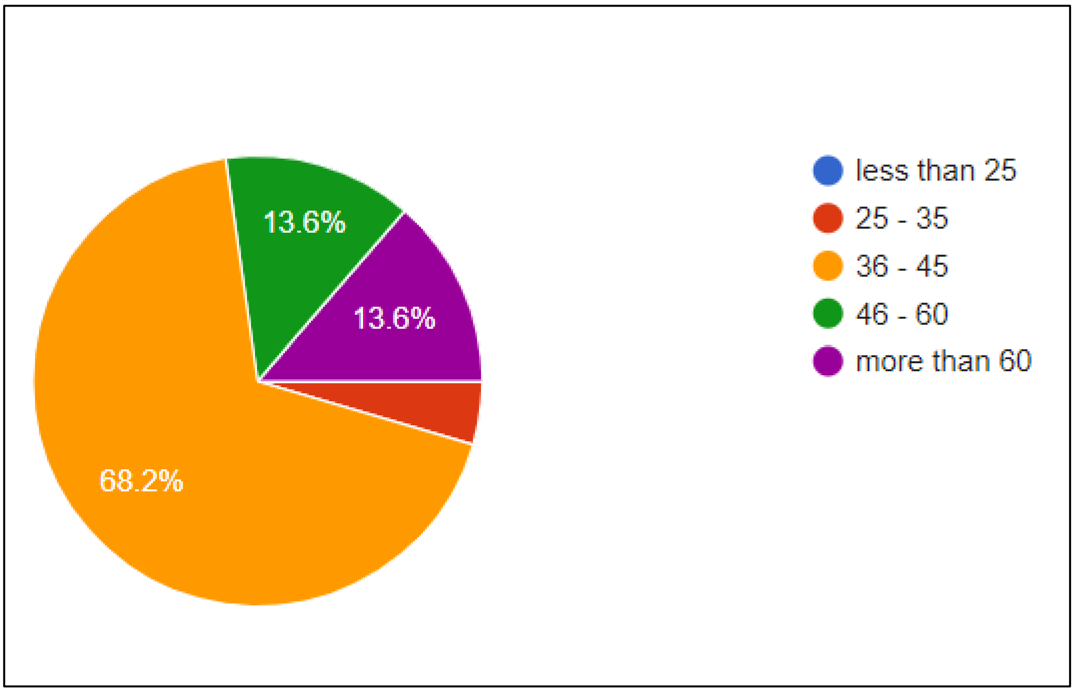
-The professional field data of the 22 Palestinian experts who participated in the study

Expert	Professional field
A	- Civil Engineer - Academic at The Palestinian Technical University Kadoorie
B	- Building Engineer - Certified Trainer at The Palestinian Engineers Association
C	- Sustainable Architecture Engineer - Academic at An Najah University
D	- Transportation Engineer - Academic at An Najah University
E	- Sustainable Architecture Engineer - Academic at An Najah University - Member at The Palestine Higher Green Building Council
F	- Green Buildings Economics Expert - Academic at An Najah University
G	- Sustainable Building Engineer - Academic at An Najah University
H	- Energy Management Engineer - Academic at An Najah University

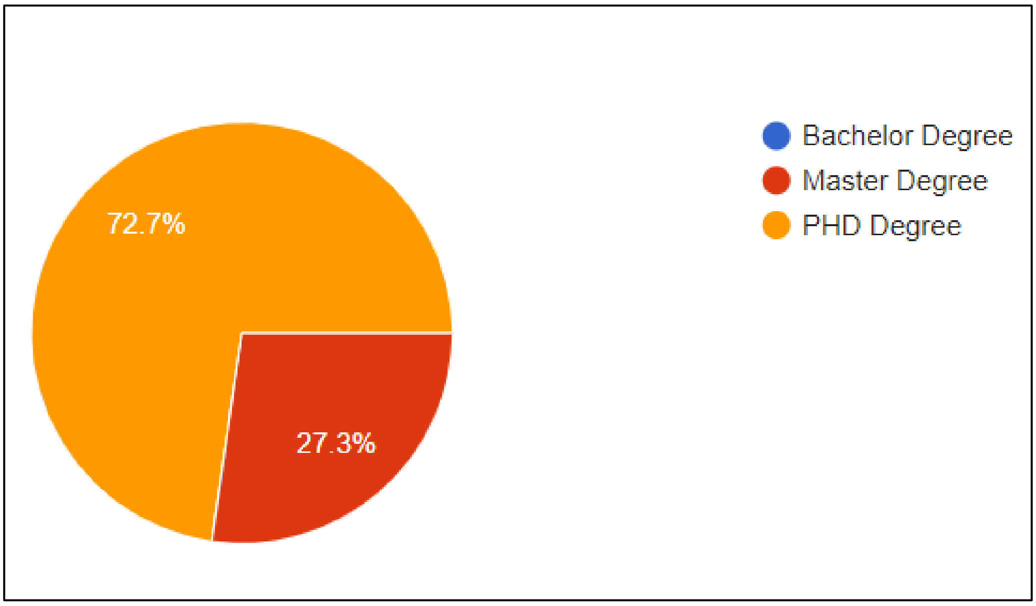
	-	Member at The Palestine Higher Green Building Council
I	-	Renewable Energy Source Expert
	-	Academic at An Najah University
J	-	Waste Water Management Expert
	-	Academic at Birzeit University
K	-	Sustainable Architectural Engineer
	-	Academic at Birzeit University
	-	Member at The Palestine Higher Green Building Council
L	-	Thermal Power Expert
	-	Academic at An Najah University
M	-	Energy Conversion Expert
	-	Academic at Birzeit University
	-	Member at The Palestine Higher Green Building Council
N	-	Mechanical Engineer
	-	Facilities Manager at the Palestinian Museum N.G. (LEED certified building)
O	-	Building Science Engineer\Architect
	-	Academic at The Palestinian Technical University Kadoorie
P	-	Sustainable architecture Engineer
	-	Academic at Islamic University of Gaza
Q	-	Water and Waste Water Treatment Engineer

	-	Academic at Palestine Polytechnic University
R	-	Architect
	-	General Administration of Buildings at The Ministry of Education and Higher Education of The Palestinian National Authority
S	-	Civil Engineer
	-	CEO at The Palestinian Green Building Council
T	-	Environmental Engineer
	-	Moderator at The Palestine Higher Green Building Council
U	-	Energy Conservation and Management Engineer
	-	Academic at An Najah University
	-	Head of The Palestine Higher Green Building Council
V	-	Civil Engineer
	-	CEO of School Buildings at The Ministry of Education and Higher Education of The Palestinian National Authority

The age data of the 22 Palestinian experts who participated in the study



-The educational level data of the 22 Palestinian experts who participated in the study



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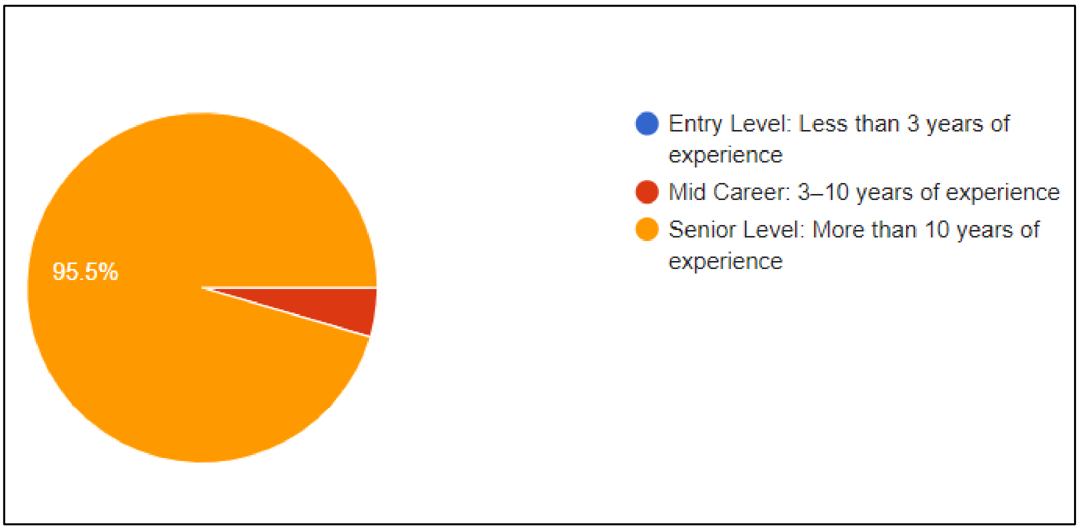
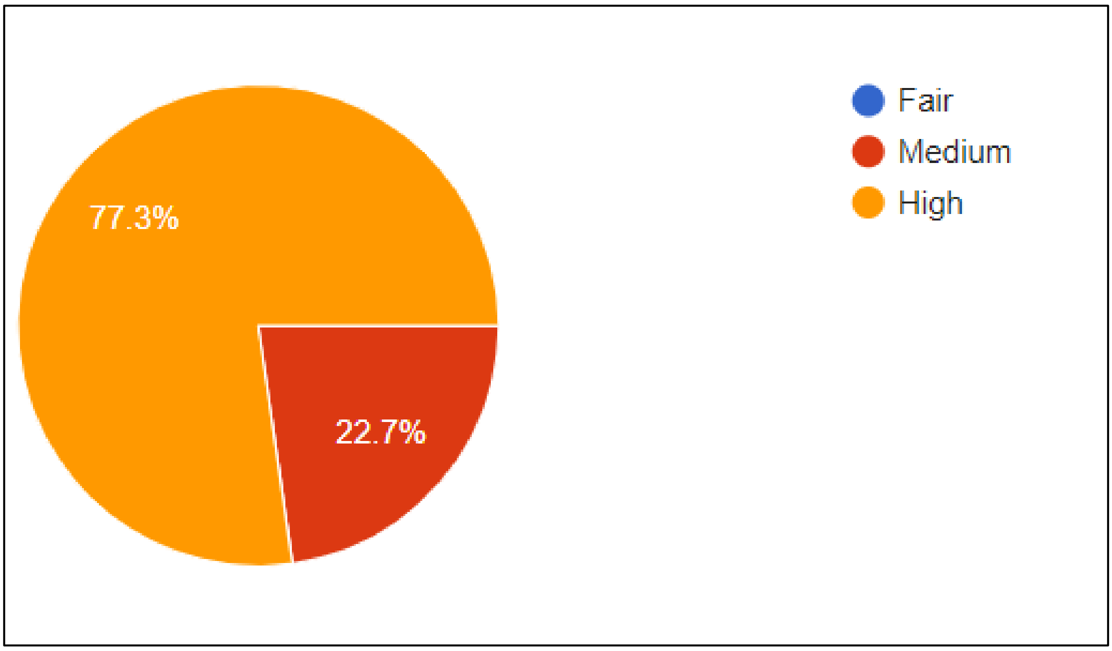
The career level data of the 22 Palestinian experts who participated in the study



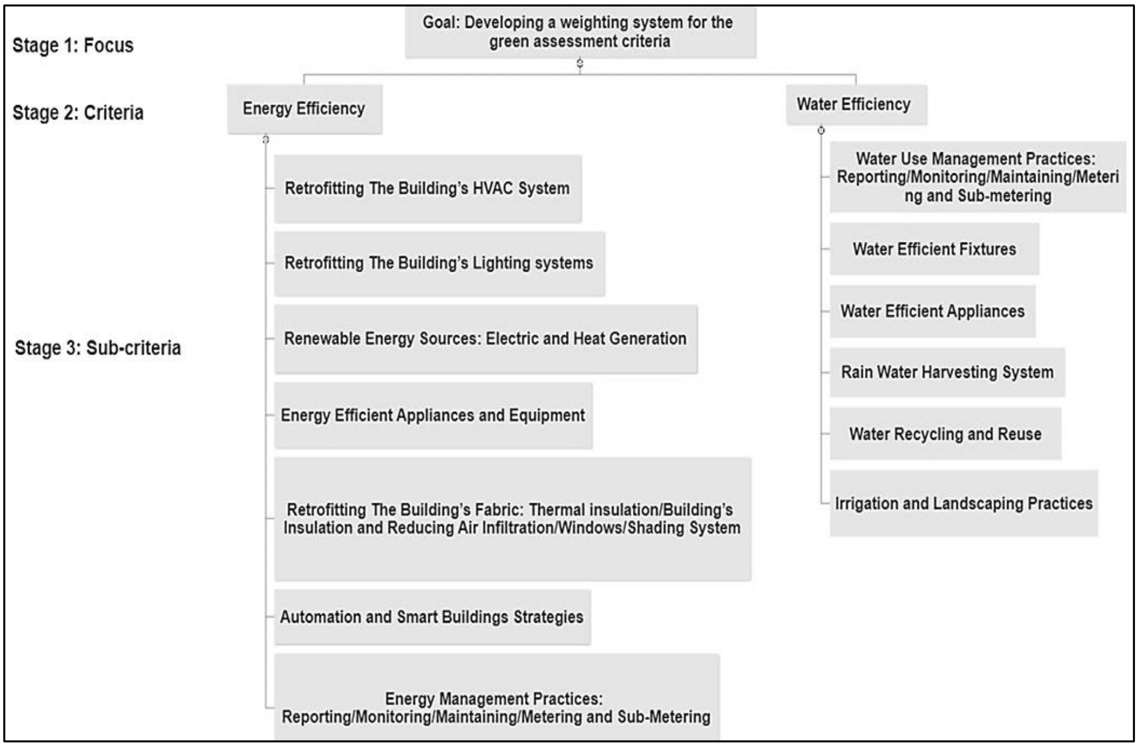
-The knowledge level of Sustainability and GBs of the 22 Palestinian experts who participated in the study



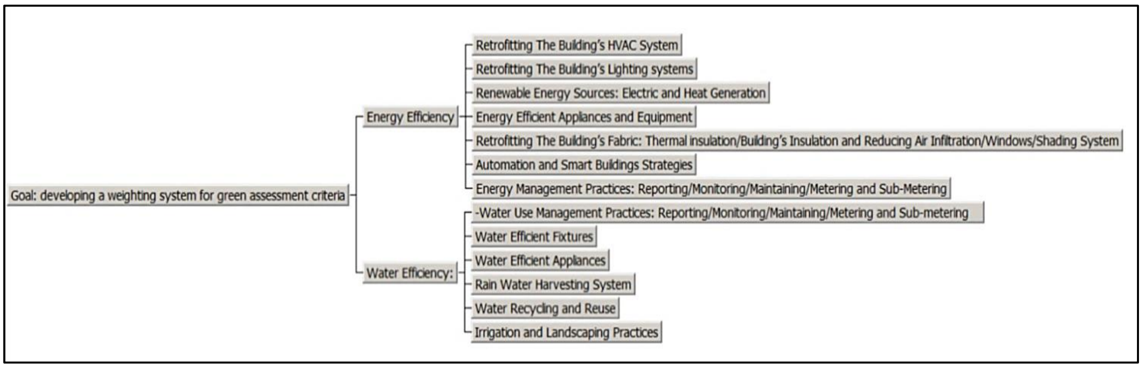
Appendix H

The hierarchy model of the problem defined by the study

-The hierarchy model for developing a weighting system for the green assessment criteria



The hierarchy model for developing a weighting system for the green assessment criteria generated from Expert Choice software

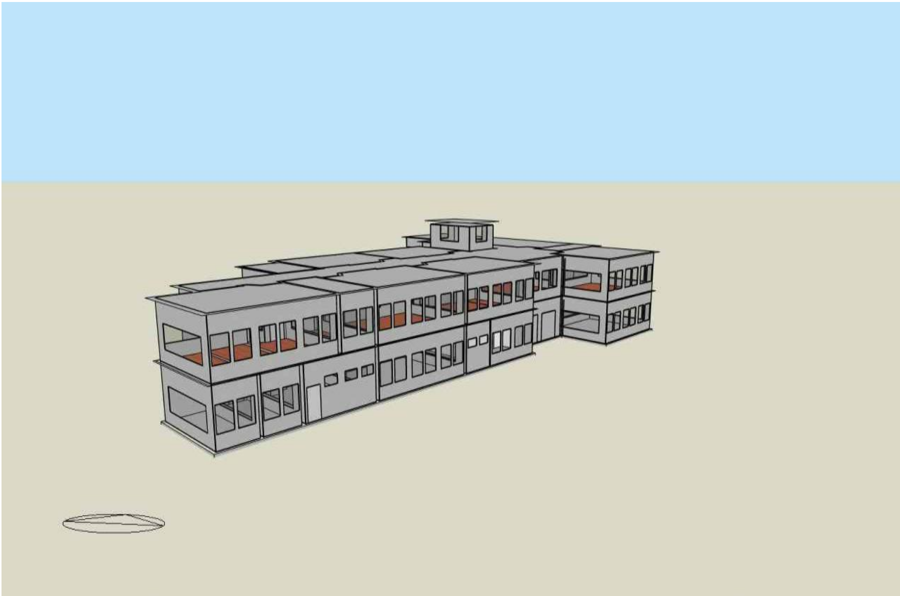


Appendix I

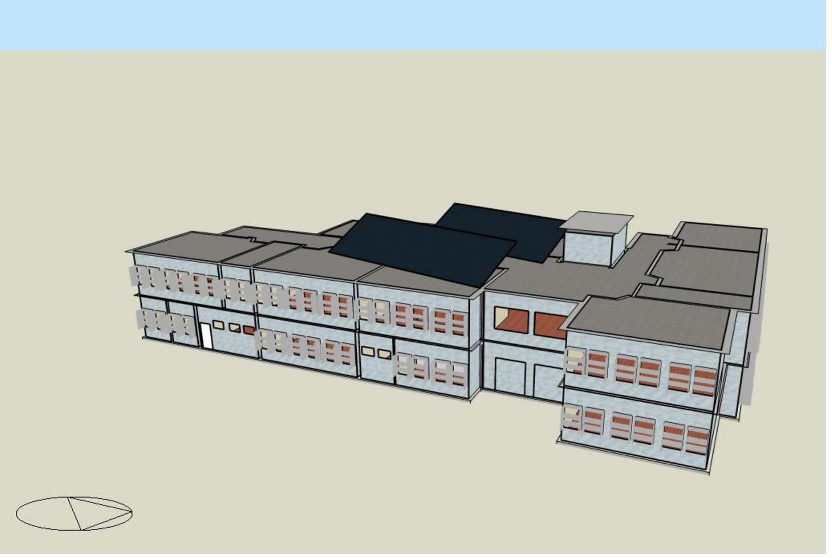
Aqqaba Green School

-Aqqaba Green School

Aqqaba School original baseline model before the retrofit as an existing building (generated from the DesignBuilder software)



Aqqaba Green School model after applying green retrofit strategies (generated from the DesignBuilder software)



Rain water harvesting tank used in Aqqaba School

-Water recycling tank used in Aqqaba School

Appendix J

Aqqaba School Energy Input Including Solar Energy (Generated from EnergyPlus 9.3)

Aqqaba School Baseline Model Energy Input

Site and Source Energy

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	133992.30	114.17	114.17
Net Site Energy	105228.94	89.67	89.67
Total Source Energy	424353.61	361.59	361.59
Net Source Energy	333260.04	283.97	283.97

Site to Source Energy Conversion Factors

	Site=>Source Conversion Factor
Electricity	3.167
Natural Gas	1.084
District Cooling	1.056
District Heating	3.613
Steam	0.250
Gasoline	1.050
Diesel	1.050
Coal	1.050
Fuel Oil No 1	1.050
Fuel Oil No 2	1.050
Propane	1.050
Other Fuel 1	1.000
Other Fuel 2	1.000

Building Area

	Area [m2]
Total Building Area	1173.57
Net Conditioned Building Area	1173.57
Unconditioned Building Area	0.00

End Uses

	Electricity [kWh]	Natural Gas [kWh]	Gasoline [kWh]	Diesel [kWh]	Coal [kWh]	Fuel Oil No 1 [kWh]	Fuel Oil No 2 [kWh]	Propane [kWh]	Other Fuel 1 [kWh]	Other Fuel 2 [kWh]	District Cooling [kWh]	District Heating [kWh]	Water [m3]
Heating	20725.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	28017.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	40676.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	14231.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	30341.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	133992.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Electricity appears to be the principal heating source based on energy usage.

Aqqaba School after the Retrofit Model Energy Input

Site and Source Energy

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	89348.26	76.13	76.13
Net Site Energy	60584.90	51.62	51.62
Total Source Energy	282965.95	241.12	241.12
Net Source Energy	191872.38	163.49	163.49

Site to Source Energy Conversion Factors

	Site=>Source Conversion Factor
Electricity	3.167
Natural Gas	1.084
District Cooling	1.056
District Heating	3.613
Steam	0.250
Gasoline	1.050
Diesel	1.050
Coal	1.050
Fuel Oil No 1	1.050
Fuel Oil No 2	1.050
Propane	1.050
Other Fuel 1	1.000
Other Fuel 2	1.000

Building Area

	Area [m2]
Total Building Area	1173.57
Net Conditioned Building Area	1173.57
Unconditioned Building Area	0.00

End Uses

	Electricity [kWh]	Natural Gas [kWh]	Gasoline [kWh]	Diesel [kWh]	Coal [kWh]	Fuel Oil No 1 [kWh]	Fuel Oil No 2 [kWh]	Propane [kWh]	Other Fuel 1 [kWh]	Other Fuel 2 [kWh]	District Cooling [kWh]	District Heating [kWh]	Water [m3]
Heating	14346.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	11449.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	25765.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	14231.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	23554.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	89348.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Electricity appears to be the principal heating source based on energy usage.

Appendix K

Yearly water use data for 15 Palestinian secondary schools -female students

School Number	School Name	School Location	Students Number	Yearly Water Consumption (m^3)	The School Average Water Use\Stu. (m^3\Stu.)
1	Ibraheem Al-Khawaja Secondary Girls School	Tulkarm	340	468	1.376
2	Al-Adaweyah Secondary Girls School	Tulkarm	629	2452	3.898
3	Al-Salaheya Secondary School for Girls	Nablus	393	165	0.420
4	Salfit Secondary Girls School	Salfit	340	270	0.794
5	Salfit Industrial Secondary School	Salfit	81	150	1.852
6	Al-Zahra Secondary Girls School	Jenin	509	295	0.580
7	Al-Bireh Secondary Girls School	Ramallah & Al Bireh	555	325	0.586
8	Al-Shayma' Secondary Girls School	Qalqilya	366	683	1.866
9	Khadija Abdeen Secondary Girls School	Hebron	427	152	0.356
10	Al-Khansa' Secondary Girls School	Ytah	530	151	0.285
11	Jericho Secondary Girls School	Jericho	552	1390	2.518
12	Halhul Secondary Girls School	Halhul	433	330	0.762
13	Dura Secondary Girls School	Dura	421	152	0.361
14	Al-Khader Secondary School for Girls	Bethlehem	413	197	0.477
15	Beit Jala Secondary Girls School	Bethlehem	429	185	0.431

Schools' Average water Use\Stu. = 1.104

جـامعـــة النجاح الوطنية

كليـــة الدراســـــات العليــــا

تطوير نظام تصنيف كفاءة الطاقة وكفاءة المياه للمباني القائمة في فلسطين باستخدام عملية التسلسل الهرمي التحليلي (AHP)

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الملخص

تحظى أنظمة تصنيف المباني الخضراء باهتمام كبير بين الحكومات في جميع أنحاء العالم، لأنها تساهم في تحقيق أهداف التنمية المستدامة؛ وتحسين قطاع البناء، الذي لا يزال مساهماً كبيراً في انبعاثات ثاني أكسيد الكربون واستنفاذ الموارد الطبيعية. تؤثر المباني سلباً على البيئة في كل مرحلة من مراحل دورة حياتها، ولكن تمثل مرحلة التشغيل والصيانة 70% إلى 90% من هذا التأثير. تزود أنظمة تصنيف المباني الخضراء أصحاب المصلحة في المشروع وصناع القرار بخريطة طريق وإرشادات لتعزيز استدامة البيئة المبنية وأدائها التشغيلي. حاليًا لا يوجد نظام تصنيف أخضر للمباني القائمة في فلسطين، ونظام التصنيف الوحيد المتاح يستهدف الإنشاءات الجديدة فقط. تهدف هذه الدراسة إلى اقتراح نظام تصنيف أخضر للمباني القائمة في فلسطين فيما يتعلق بمعيارين: كفاءة الطاقة وكفاءة المياه، حيث تزن هاتان الفئتان من 50% إلى 70% بين معظم الأنظمة. تمت مراجعة ستة أنظمة تصنيف بناء أخضر عالمية و محلية لتطوير أهم المعايير الفرعية لفئات الطاقة والمياه لتقييم "خضرة" المباني القائمة. تمت مقابلة 22 خبيراً فلسطينياً لتحديد أولوية و أهمية المعايير الفرعية المطورة في كلتا الفئتين، وتم إجراء عملية التسلسل الهرمي التحليلي كنهج متعدد المعايير لصنع القرار لتحليل الردود من خلال برنامج "خيار الخبراء". ونتيجة الدراسة هي نظام فلسطيني مقترح لتقييم كفاءة الطاقة وكفاءة المياه للمباني القائمة ، والذي يتكون من مجموعة من الأوزان ونظام تصنيف من أربعة مستويات، حيث أن عملية التسلسل الهرمي التحليلي مسؤولة عن نظام تحديد الوزن المطور للمعايير والمعايير الفرعية المختارة وفقًا لأولويتها. أخيرًا ، للتأكد من صلاحية النظام المطور، تم تقييم حالة

افتراضية في فلسطين باستخدام نظام الريادة في تصميمات الطاقة والبيئة (LEED) للتشغيل والصيانة، بالإضافة إلى نظام GBRS-EX الفلسطيني لكفاءة الطاقة والمياه. توضح النتائج ضرورة حصول فلسطين على نسختها الخاصة للمباني القائمة حيث لا يمكن اعتماد تخصيص إصدارات أنظمة عالمية أخرى نظرًا لأن أنظمة تصنيف البناء الأخضر تتأثر بالخصائص البيئية والثقافية الفريدة للدولة التي تم إنشاؤها فيها. توصي الدراسة بمزيد من البحث لتطوير أنظمة تصنيف بناء أخضر في فلسطين للمباني القائمة يشمل فئات أخرى و أنواع محددة من المباني.

الكلمات المفتاحية: استراتيجيات التعديل التحديثي الأخضر ، كفاءة الطاقة ، كفاءة المياه عملية ، التسلسل الهرمي التحليلي.