JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

ASSESSMENT OF ENVIRONMENTAL SUSTAINABILITY OF BUILDING CONSTRUCTION: A CASE OF WOLISO TOWN

A research thesis submitted to the School of Graduate Studies, Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree Master of Science (MSc) in Construction Engineering and Management

By FIRIKOT MELAKU KEBEDE

MARCH 2025
JIMMA, ETHIOPIA

JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

ASSESSMENT OF ENVIRONMENTAL SUSTAINABILITY OF BUILDING CONSTRUCTION: A CASE OF WOLISO TOWN

A research thesis submitted to the School of Graduate Studies, Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree Master of Science (MSc) in Construction Engineering and Management

Advisor: DR. LUCY FELEKE

Co-Advisor: Engr. BONTU WOYESSA

MARCH 2025
JIMMA, ETHIOPIA

DECLARATION

I declare that this research thesis titled "Assessment of Environmental Sustainability of Building Construction: A Case of Woliso Town" is my original work and has not been submitted as a requirement for the award of any degree in Jimma University or anywhere else.

Firikot Melaku Kebede	___________________	_________________
NAME OF STUDENT	SIGNATURE	DATE

As research Advisor, we hereby certify that we have read and evaluated this thesis paper prepared under our guidance, by **Firikot Melaku Kebede** entitled "ASSESSMENT OF ENVIRONMENTAL SUSTAINABILITY OF BUILDING CONSTRUCTION: A CASE OF WOLISO TOWN" and recommend and would be accepted as a fulfilling requirement for the Degree Master of Science (MSc) in Construction Engineering and Management.

Advisor: Dr. Lucy Feleke_________________________Date _________

Co-Advisor: Engr. Bontu Woyessa ________________ Date __________

ABSTRACT

The rapid expansion of building construction in Ethiopia has raised concerns about environmental sustainability, necessitating the green building practices. This study assesses the environmental sustainability of building construction projects in Woliso town, examining the existing conditions of buildings, stakeholder awareness, and challenges in implementing sustainable construction methods.

A descriptive mixed-method approach was employed, utilizing site observations, questionnaires based on the Leadership in Energy and Environmental Design (LEED) checklist, and interviews with key stakeholders, including tenants, building owners, environmental protection officers, and construction professionals. Data was analyzed through Statistical Package for the Social Sciences (SPSS) and thematic analysis of transcription, coding and verification steps. The findings reveal significant deficiencies in green building standards, with many buildings lacking essential features such as urban heat mitigation, energy efficiency, and water conservation measures.

Key issues identified include the Urban Heat Island effect, excessive energy and water consumption, and poor indoor environmental quality. Barriers to sustainability adoption include weak regulatory frameworks, limited expertise, and misconceptions about the costs associated with sustainable construction. While stakeholders demonstrated moderate awareness of environmental sustainability principles, this knowledge has not effectively translated into practice. The study underscores the urgent need for policy intervention, capacity-building programs, and regulatory enforcement to enhance sustainable construction practices. By integrating environmental sustainability principles into local building practices, Woliso town can foster a more resource-efficient and environmentally responsible built environment.

Keywords: *Sustainability, Environmental Sustainability, Green Building, Building Construction, LEED, Ethiopia.*

ACKNOWLEDGMENTS

First and for most, I would like to thank almighty God for giving me the strength to bring my longtime dream and effort into reality. Then, I would to like to express my deepest gratitude and appreciation to my advisors, **Dr. Lucy Feleke** and **Engr. Bontu Woyessa** for their time and unreserved support during preparation of this thesis.

I am also indebted to express my thanks to my lovely families as well as friend giving love and support during my university stay. Finally, I thank all those who assisted me with ideas, comments, and contacts for your countless contributions.

LISTS OF TABLES

LISTS OF FIGURES

TABLES OF CONTENTS

LIST OF ABBREVIATIONS AND ACRONYMS

BREEAM	Building Research in Energy and Environmental Assessment Management
CO_2	Carbon Dioxide
CFL	Compact Fluorescent Lamps
EB	European Building
ERB	Ethical Review Board
EPA	Environmental Protection Agency
EU	European Union
FDRE	Federal Democratic Republic of Ethiopia
GHG	Greenhouse Gas
HVAC	Heating, Ventilation, And Air Conditioning
IEQ	Indoor Environmental Quality
LEED	Leadership in Energy and Environmental Development
LED	Light Emission Diode
SA	Sustainability Assessment
SPSS	Statistical Package for the Social Sciences
SBT	Sustainable Building Tool
UHI	Urban Heat Island
US	United States
USGBC	United States Green Building Council

CHAPTER ONE

INTRODUCTION

1.1. Background of Study

Construction project development potentially contributes to economic and social development and enhances both the standard of living and quality of life. Despite this, construction activities affect the environment throughout the life cycle of development. These impacts occur from initial work on-site through the construction period, operational period, and final demolition when a building comes to an end of its life. Even though the construction period is comparatively shorter than the other stages of a building's life, it has diverse significant effects on the environment [1, 2]. The construction industry is recognized as a vital sector for achieving sustainability objectives because it encompasses economic development, social development, and environmental protection [3, 4]. By considering the life cycle of a building, sustainable construction aims to meet the needs of users while minimizing environmental impact and reducing life cycle costs [5].

One effective approach to achieving environmental sustainability in building construction is the implementation of greener and more sustainable practices, such as industrialized buildings [6, 7]. Industrialized buildings promote sustainability by creating a controlled production environment, minimizing waste generation, using energy-efficient building materials, and ensuring practical logistics. By adopting these practices, the construction industry can contribute to better investment in environmental technologies and long-term economic stability [3, 8]. Sustainable construction is an emerging issue for the construction industry worldwide [9, 10]. It is crucial for construction firms to implement sustainable business practices because of the industry's significant economic, social, and environmental impacts [2]. Implementing sustainable business practices in the construction industry is crucial for two reasons. First, the construction industry faces challenges posed by sustainability, which necessitate the adoption of sustainable practices. Second, as one of the largest industries in both developed and developing countries, the construction industry has a substantial influence on environmental sustainability [2, 6, 11, 12]. There is general agreement that the building sector has a significant impact on the environment. The natural environment, economy, health, and productivity are all greatly impacted by the constructed environment. Therefore, many studies have indicated that all forms of buildings, residential and nonresidential, contribute nearly 50 % of the total carbon emissions [13]. This is an implication for the application of sustainable development requirements and environmental sustainability issues and recommendations to the construction industries [14-16]. When developing and maintaining buildings, it uses both renewable and non-renewable natural resources and produces waste and emissions. In essence, it affects the environment throughout the life of a building [17]. In Ethiopia, buildings (both new and existing) are being created at an increasing rate even though no entity is in charge of evaluating and certifying them. Hence, the consideration of sustainable building principles and requirements is the basis for current and future construction industries and healthy environments.

1.2. Statement of the Problem

While construction activities contribute to economic growth and infrastructure development, they also lead to severe environmental consequences, including excessive energy consumption, inefficient water usage, increased carbon emissions, and the depletion of natural resources. The building construction sector significantly influences environmental sustainability, particularly in rapidly urbanizing regions like Ethiopia. One of the most pressing concerns in urban areas is the Urban Heat Island (UHI) effect, where dense clusters of buildings and paved surfaces absorb and retain heat, raising local temperatures and intensifying energy demands. This increased energy content is later emitted back into the atmosphere, heating up the surrounding urban environment, which can increase water consumption and energy loads, especially in summer [18-20].

During construction projects, care must be taken to reduce waste and energy consumption where possible and to protect the natural environment around the site. Therefore, it has a huge responsibility to aid environmental sustainability. In response to this, there is growing consensus among organizations committed to environmental performance targets that appropriate strategies and actions are needed to make building activities more sustainable.

Sustainable construction is an approach widely sought by governments, environmentalists, and other stakeholder groups who recognize its benefits [21]. Globally, approximately 171 countries have now set up their environmental management systems and frameworks to solve environmental issues resulting from greenhouse gas emissions [22]. Industry practitioners have begun to pay attention to controlling and correcting the environmental damage due to their activities. Architects, designers, engineers, users, and others involved in the building process have a unique opportunity to reduce environmental impact through the implementation of sustainability objectives from the design development stage of a building project to the post-building stage. However, understanding sustainable building processes in the construction industry is at an infant stage of research and application, which requires further exploration and study. For instance, the concept of a sustainable building process is a new notion in developing countries, including Ethiopia, and is hardly practiced by construction firms in the country [23, 24]. The advancement of construction technologies in recent times has given the sector an opportunity to evolve in design, energy efficiency, water usage, waste disposal, and so on, which is the reason to study existing buildings projects that have been exposed to the advancement.

The Federal democratic republic of Ethiopia Constitution further provides in article 92(2) that the design and implementation of development programs and projects in the country should not damage or destroy the environment and sub article (4) states that the government and citizens shall have the duty to protect the environment. Therefore, provisions require the consideration of environmental concerns while designing and implementing socioeconomic developmental policies and projects, including building construction [25]. Nevertheless, there is a knowledge and practice gap in the recommended standard criterion in building construction [26]. In Ethiopia, there is a noticeable gap between policy and practice regarding sustainable building construction. Although the government has recognized the importance of environmental sustainability, there is no comprehensive regulatory framework or enforcement mechanism to ensure that new and existing buildings meet green construction standards. This issue is particularly evident in Woliso town, where rapid construction growth has taken place without sufficient consideration for sustainability measures. Many buildings lack essential green features such as energy-efficient designs, proper ventilation, water conservation systems, and effective waste management strategies. Given these challenges, this study seeks to assess the environmental sustainability of building construction projects in Woliso town by examining existing conditions, evaluating stakeholder knowledge and practices, and identifying key barriers to sustainable construction. The findings will provide practical recommendations for integrating green building principles into Ethiopia’s construction sector, ultimately contributing to a more resource-efficient and environmentally responsible built environment.

1.3. Research Questions

Specific research questions that were addressed:

1. What are the existing situations of the buildings in relation to green building standard criteria in the selected site?
2. What is the knowledge and practice of construction stakeholders, environmental protection offices and owners regarding the environmental sustainability concept in building construction?
3. What are factors affecting the environmental sustainability of buildings in Woliso town?

1.4. Objectives

1.4.1. General objective

The general objective of this study is to assess the consideration of environmental sustainability concepts in building construction projects in Woliso town, Southwest Shewa zone, Ethiopia.

1.4.2. Specific Objectives

1. To assess the existing nature of the building in relation to green building standard criteria in the selected site.
2. To assess knowledge and practice of construction stakeholders, environmental protection offices and owners regarding the environmental sustainability concept in building construction.
3. To identify factors that affect environmental sustainability in building construction in the setting.

1.5. Scope of the Study

The research paper was conducted within the Woliso town building construction project in the town. This paper's scope is limited to the assessment of the existing nature of building construction (Heat Island effect, Energy-efficient equipment, Natural lightning and ventilation, Innovative Wastewater technology, Water use reduction) with the concepts of environmental sustainability. Generally, in this thesis consideration was given to the environmental aspect of building sustainability and its relation to socioeconomic factors because it is the fundamental idea that consultants, contractors, local authorities, and the society as a whole need to consider in their way of moving towards achieving sustainability.

1.6. Significance of the Research

The findings of this study can help to create awareness about environmentally sustainable buildings and will provide ample information for designers, local authorities, and project managers with guidance to make informed decisions about facilities, building techniques, materials, and other considerations to create a healthier building environment for society. It can also be a part of a case library study related to sustainable building as a reference material for similar studies in the future. As it is a new concept in the area, the study results are expected to potentially fill the gap between sustainable environmental issues and building construction.

1.7. Organization of the Study

This paper is divided into five chapters in terms of structure. The introduction is given in the first chapter. This section covers the study's background, problem statement, research questions, research objectives, study scope, the significance, and limitations of the study. The second chapter addresses the body of knowledge (review of the related literature) regarding the idea of environmentally friendly building construction. The third chapter explains the methods employed to accomplish each research goal as well as how the study was conducted. In light of the foregoing, this report provides an analysis and interpretation of the data acquired in the fourth chapter. The conclusion and crucial suggestions are provided in the final chapter.

1.8. Limitations of the study

Studying has several strengths. Firstly, it employed multiple methods of data collection, such as surveys, interviews, and site inspections, to provide a comprehensive understanding of the existing nature of the building and Secondly, It included multiple stakeholders, such as construction experts, and property owners, environmental protection offices to provide the knowledge and practices of construction stakeholders regarding environmental sustainability a and holistic view of the factors that affect environmental sustainability in building construction. However, as with any study, there are also limitations that must be acknowledged. The study may have a limited sample size and thus limit the generalizability of the findings.

CHAPTER TWO

LITERATURE REVIEW

2.1 Sustainability and Sustainable Development

Sustainability is ensuring that our activities in relation to nature do not put the future of the planet by challenging its capacity to renew and heal. According to Omer et al [27] the demand for natural resources now exceeds nature's regenerative capacity, which means we are exploiting nature more than it is replenishing itself [27, 28] This requires measures of reforestation and greening and resorting to clean energy, both to maintain a balance with its regeneration and healing, so that our greenhouse gas emissions will not exceed the planet's capacity to absorb them. Buildings must respond to the environment from the design stage and settle when they are to decrease confronting nature [28].

Sustainable development is about ensuring a better quality of life for everyone, now and for generations to come. This requires meeting four key objectives simultaneously in the world as a whole: social progress that recognizes the needs of everyone; effective protection of the environment; prudent use of natural resources; and maintenance of high and stable levels of economic growth and employment. One of the most important aspects of sustainable development goal is also in a constructed environment is adaptability to social, economic, and environmental conditions, and one of its important characteristics is efficient planning, consistency facilitation, and design for change, reducing costs and protection, and improving natural and environmental values [29].

2.2 Sustainable Construction

Sustainable construction is defined as "the creation and responsible management of a healthy built environment based on resource-efficient and ecological principles". Sustainably designed buildings aim to reduce their impact on the environment through energy and resource efficiency. The main target of sustainable building design is to develop "environmentally friendly construction practices" that contribute to saving energy, water, and raw materials; minimizing water surplus and greenhouse gas emissions; and consuming reuse and recycling of materials to create houses that are comfortable, clean, safe, and productive[30]. Sustainable construction aims to minimize environmental impact by reducing resource consumption, waste, and pollution[31]. It involves energy-efficient designs, eco-friendly materials, and sustainable site selection. The adoption of green building practices is a crucial strategy to mitigate climate change [32].

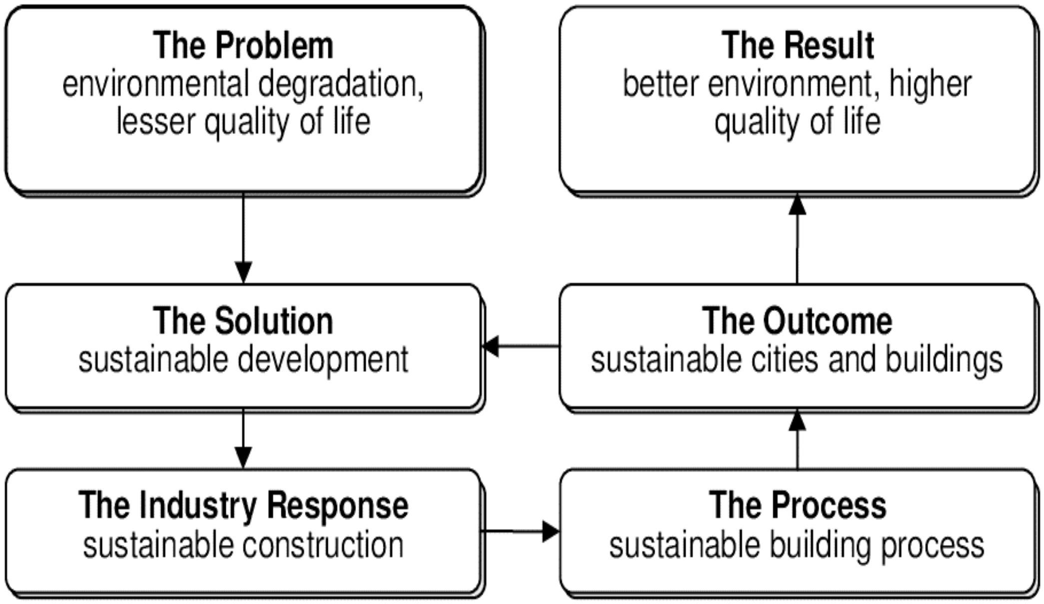

Figure 2.1: A simplified road map for sustainable construction[33]

The diagram emphasizes the importance of sustainable practices in tackling environmental issues and building a future that supports both human well-being and ecological harmony. It illustrates the journey from identifying the issue of environmental degradation to achieving a better quality of life through sustainable development practices. Here's the flow:

- **The Problem:** At the core is environmental degradation, which negatively impacts the quality of life.
- **The Solution:** The answer lies in sustainable development, which aims to address these challenges.
- **The Industry Response:** In the context of construction, this translates to sustainable construction practices.
- **The Process:** This involves implementing a sustainable building process that reduces environmental harm while meeting human needs.
- **The Outcome:** When done effectively, it leads to sustainable cities and buildings that support long-term ecological balance.
- **The Result:** Ultimately, this results in a healthier environment and an improved quality of life for all.

2.3 Impacts of construction activities on the environment and construction industry

The construction business also has a negative impact on the building's residents. For instance, building owners are exposed to indoor air quality conditions that affect people health, safety, welfare, and performance through their interiors [34]. Additionally, the pain caused by the heat that building occupants face throughout the summer worsens their bodily and mental health, including heart disease, insomnia, migraines, lethargy, boredom, and low arousal [35]. There are concerns about how to improve construction practices to minimize their effects on the natural environment. The environmental impact of construction, green buildings, designing for recycling, and eco-labeling of building materials have captured the attention of building professionals across the world. Building performance is a major concern in the building industry, and environmental building performance assessment has emerged as one of the major issues in sustainable construction [1].

Climate resilience in construction focuses on designing buildings that withstand environmental challenges such as extreme heat, water scarcity, and flooding [32]. A study reported by Haileleul et al [36] on the evaluation of selected Addis Ababa buildings with respect to the green building features showed that most of the sampled buildings had problems in their indoor environment quality and energy usage, were indifferently layout functionally, and had a disorganized waste management system compared to green buildings. This implies that it is important to apply some kind of standardized environmental labeling mechanism to the buildings that can help environmental integration and resource management. A study conducted by Tafesse et al [37] pointed out that the Ethiopian construction industry wastes materials is at a rate of more than 21% which is a significant amount when compared to the results from building construction sites in developed countries. Major cities in Ethiopia and other developing countries, where most of the urbanization will occur, will consume large amounts of energy, and emit energy-related greenhouse gas (GHG) emissions.

2.4 Green Building

Green building refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a buildings life cycle: from planning to design, construction, operation, maintenance, renovation, and demolition [38]. Green Buildings impacts on occupants health and productivity and results revealed that buildings with green features and environmentally friendly materials provide better indoor environment quality for their residents compared with conventional buildings, which implies that high indoor environment quality leads to less indoor pollution and improves occupants health and productivity compared with conventional buildings [39].

2.5 Social and Economic Benefits of Green Buildings

Green buildings offer long-term benefits, including improved indoor air quality, occupant health, and energy savings (Dixit et al., 2012). Studies show that sustainable construction reduces long-term operational costs by up to 30% through energy-efficient lighting and water conservation (Olubunmi et al., 2016). Furthermore, green buildings increase productivity in workspaces and enhance property value [31]. In practical terms, a green building includes, but is not limited to, the following aspects:

- Using passive techniques such as solar and wind for natural heating, cooling, and daylighting.
- Landscaping with native plants to conserve water used in irrigation.
- Building quality, durable structures.
- Air-tight designed spaces with good insulation and ventilation appropriately.
- Incorporating salvaged, recycled, and sustainably harvested materials.
- Maintaining healthy indoor air quality with appropriate construction techniques and materials.
- Using energy-efficient and water-saving appliances and fixtures; and
- Reducing and recycling construction waste.

2.6 Environmental sustainability

The idea of environmental sustainability is to leave the Earth in better or better shape for future generations than we find it for ourselves. By definition, human activity is only environmentally sustainable when it can be performed or maintained indefinitely without depleting natural resources or degrading the natural environment [40]. The economy exists within society, and both the economy and society exist within the environment. Sustainability indicators measure the extent to which these boundaries are respected.

2.7 Environmentally sustainable buildings

According to [13], environmentally sustainable buildings are known to have low-to-none carbon emissions through ways devised to keep them functional. This requires resorting to natural measures in heating and cooling; ventilation and day lighting strategies; proper orientation and building shape; placement of glazing; and incorporating natural and clean energy options, such as solar energy and biofuels, in the design of the building [41].

Eco-friendly construction involves the use of materials and processes that are resource-efficient and environmentally responsible throughout the life cycle of a building. Eco-friendly construction companies are used when building your facility [21, 42]. The use of heat-reflective surfaces, such as light-colored pavements and roads, can help reduce the urban heat island effect. Dark-colored surfaces absorb more heat, leading to higher ambient temperatures [43]. Without energy-efficient roofing, a building may experience higher energy consumption, increased cooling costs, and a larger carbon footprint[44]. By using water-efficient fixtures and fittings, such as low-flow toilets, faucets, and showerheads, less water is wasted during daily activities [45]. This helps conserve water resources and reduces the strain on freshwater sources. By blocking direct sunlight during hot periods, shading devices reduce the need for air conditioning and cooling energy [46]. So, this leads to energy savings and decreased reliance on fossil fuels, resulting in reduced greenhouse gas emissions. Additionally, urban heat management strategies, such as cool corridors, green infrastructure, and proper ventilation systems, can help to combat excessive heat in densely populated areas [47]. The efficiency of heating, ventilation, and air conditioning (HVAC) systems significantly affects energy consumption in buildings. High-efficiency HVAC systems are designed to minimize energy waste and maximize performance [48].

The choice of lighting systems can have a substantial impact on energy consumption. LED (Light Emitting Diode) lighting is highly energy-efficient and has a longer lifespan compared to traditional incandescent or fluorescent lighting [49]. By reducing the need for artificial lighting and temperature control systems, buildings can lower their energy consumption and contribute to environmental sustainability [50]. Incorporating renewable energy sources, such as solar panels or wind turbines, into buildings and infrastructure reduces dependence on fossil fuels. Renewable energy is clean, abundant, and does not produce harmful emissions or pollution during operation

[51]. By incorporating natural light, views of nature, and visually pleasing elements, individuals can experience a sense of calm and connection to their surroundings [52]. This promotes a sustainable approach to architecture and urban planning, enhancing the overall quality of life while minimizing the need for artificial lighting. Using natural lighting, through proper window placement and design can reduce the need for artificial lighting during daylight hours, further saving energy and promoting environmental sustainability. It reduces the reliance on electricity generated from non-renewable sources and decreases the greenhouse gas emissions associated with energy production [53].

2.8 Ethiopian policies and regulations on sustainable construction

Ethiopia has introduced various policies to promote sustainability in construction, such as the Environmental Impact Assessment Proclamation No. 299/2002 and Ethiopian Building Code Standards (EBCS). However, these policies lack strict enforcement and integration with international green building standards such as Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Methodology (BREEAM) [54].

2.9 Sustainability assessments and approaches

The purpose of sustainability assessments is to gather and report information for decision making during different phases of building construction, design, and use. The primary role of building sustainability assessment methods is to verify and present building characteristics using selected and verifiable standards. A building is assessed on the basis of an extensive selection of criteria from various domains that try as best they can to keep to the goals and principles of sustainable development by considering environmental, economic, and social aspects [55]. A variety of sustainability assessment tools are globally available on the construction market from the following:

- Building Research Establishment Environmental Assessment Methodology (BREEAM) of United Kingdom
- Leadership in Environmental & Energy Design (LEED) by the United States Green Building Council (USGBC).
- Sustainable Building Tool (SB Tool) by the International Initiative for a Sustainable Built Environment.

2.10 LEED for Existing Buildings

LEED was developed by the USGBC, a non-profit organization with a motivation for a demand for a system that could be used to assess and evaluate the performance of construction and design from a standpoint to their sustainability in 1998 for commercial constructions. LEED Operation and Maintenance is one of the rating systems branches of the LEED Green Building Rating System. It is developed for commercial and institutional buildings that already exist [56, 57]. The rating system can be applied to projects such as: existing buildings, commercial centers, schools, hospitals, data centers, and warehouses and distribution centers. The rating system is a support and guide for property owners and encourages the implementation of sustainable actions to reduce the environmental impact of the properties [58].

After over two decades of development, LEED has become the most popular GBRS globally based on the number of certified projects and countries adopting it [59, 60]. As of June 2022, there were about 60,549 LEED-certified projects across 167 countries and territories. The LEED rating schemes evaluate the sustainability of new and existing commercial, institutional, and residential buildings. Environmental factors account for the majority of LEED assessment credits, with six out of nine main categories: Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor Environmental Quality[61]. Additionally, LEED acknowledges the importance of sustainable design expertise, design measures, and local conditions by awarding credits under the Integrative Process, Innovation, and Regional Priority categories. The main categories in the LEED rating system include Integrative Process (1%), Location and Transportation (16%), Water Efficiency (11%), Sustainable Sites (10%), Energy and Atmosphere (33%), Materials and Resources (13%), Indoor Environmental Quality (16%), Innovation (6%), and Regional Priority (4%). The rating levels are Certified (40–49 points), Silver (50–59 points), Gold (60–79 points), and Platinum (≥ 80 points). According to the LEED criteria, parameters such as heat island effect, water efficiency, energy efficiency, and indoor environmental quality are commonly evaluated criteria in most countries[61].

2.10.1 Heat Island Effect

Urban heat island (UHI) manifests as the temperature rise in built-up urban areas relative to the surrounding rural countryside, largely because of the relatively greater proportion of incident solar energy that is absorbed and stored by man-made materials. The direct impact of UHI can be significant on both daytime and night-time temperatures, and the indirect impacts include increased air conditioning loads, deteriorated air and water quality, reduced pavement lifetimes, and exacerbated heat waves. Modifying the thermal properties and emissivity of roofs and paved surfaces and increasing the vegetated area within the city are potential mitigation strategies [62, 63].

The increase of land surface temperature caused by UHI effect will definitely influence material flow and energy flow in urban ecological systems, as well as alter their structure and functions, exerting a series of ecological and environmental effects on urban climates, urban hydrologic situations, soil properties, atmospheric environment, biological habits, material cycles, energy metabolism and residents' health. Through the improvement of energy efficiency, urban landscape optimization, green roof construction, high reflectivity material utilization and green land cultivation, UHI effects could be significantly mitigated [64].

2.10.2 Water Efficiency

Water, a fundamental and indispensable resource necessary for the survival of living beings, has become a pressing issue in numerous regions worldwide due to scarcity. Urban areas, where the majority of the global population reside, witness a substantial consumption of blue water, particularly in commercial buildings. This study investigates the potential for enhancing water efficiency within an ongoing high-rise office building construction situated in a tropical climate. The investigation utilizes the green building guidelines of leadership in energy and environmental design (LEED) through a case-study-based research approach. Strategies included using efficient plumbing fixtures (such as high air–water ratio fixtures and dual-flush toilets), the selection of native plants, implementing a suitable irrigation system, introducing a rainwater harvesting system (RWHS) and improving the mechanical ventilation and air conditioning (MVAC) system. The results showed a 55% reduction in water use from efficient fixtures, a 93% reduction in landscaping water needs and a 73% overall water efficiency with a RWHS from the baseline design [65].

2.10.3 Energy Efficiency

The energy sector worldwide faces evidently significant challenges that every day become even more acute. Innovative technologies and energy efficiency measures are nowadays well known and widely spread, and the main issue is to identify those that will be proven to be the more effective and reliable in the long term. With such a variety of proposed measures, the decision maker has to compensate environmental, energy, financial and social factors in order to reach the best possible solution that will ensure the maximization of the energy efficiency of a building satisfying at the same time the building's final user/occupant/owner needs[66].

2.10.4 Indoor Environmental Quality

The indoor environmental quality (IEQ) of buildings plays a crucial role in various aspects of occupants' lives and the building's overall performance. IEQ encompasses factors such as indoor air quality, thermal comfort, lighting, and acoustics. These elements significantly impact on the health, productivity, and well-being of those who occupy the building. Poor IEQ can lead to health issues like respiratory problems, headaches, and fatigue, which in turn reduce productivity and increase absenteeism[67]. Additionally, maintaining high IEQ can enhance occupants' comfort and satisfaction, leading to improved mental and physical well-being [68].

From an economic perspective, good IEQ can lower lifecycle costs by reducing the need for medical treatments and improving employee retention and performance[67]. Furthermore, optimizing IEQ can lead to energy savings. For instance, effective ventilation and natural lighting can reduce reliance on artificial lighting and HVAC systems, thereby decreasing energy consumption [69]. Overall, investing in IEQ improvements not only benefits the occupants but also contributes to the sustainability and efficiency of the building[67-69].

2.11 Knowledge, Attitude and Practice of Stakeholder on Green Building concepts and standards

The knowledge, attitude, and practice of stakeholders regarding green building concepts and standards are crucial in the context of new regulations and policies related to climate change. The construction industry faces significant pressure to enhance the sustainability of its practices. Many organizations are now aligning their operations with government legislative targets, such as reducing carbon emissions, and are considering the environmental, social, and economic performance of buildings[70]. Sustainable construction is a rapidly evolving field, driven by technological advances, legislative changes, and increasingly educated clients. This dynamic environment requires construction professionals to stay updated with new information, best practices, technologies, and changing legislation at local, national, and international levels[70]. Despite the global attention on sustainability in the built environment, many developing countries have not made substantial progress, leaving many sustainability aspects unaddressed[71].

Research on multiple stakeholders' perspectives has recently gained importance in green building studies, as it highlights the influence, interest, and engagement of various stakeholders. This research is essential for improving decision-making processes and promoting sustainability in the built environment[72]. Understanding the dynamic relationships and interactions between multiple stakeholders is critical for advancing sustainable practices[72]. Sustainability ill-practices in the construction industry can significantly hinder the achievement of governmental targets for carbon and energy reduction[72]. Awareness of green building practices involves strategic models and promotional activities that help people understand the importance of specific issues and the goals necessary to accomplish tasks[72].

Poor environmental management of construction projects contributes significantly to environmental degradation. Although the global industry has introduced changes such as the development of green materials and green building certification, stakeholders have made limited efforts to bring about substantial improvements[73]. Lifecycle Assessment (LCA) is a valuable tool for evaluating a building's environmental impact from material extraction to demolition[74]. The selection of sustainable materials, such as locally sourced and recyclable materials, can significantly reduce carbon footprints. However, Ethiopia still lacks an integrated framework for LCA implementation in construction projects[75].

2.12 Factors affecting the environmental sustainability of buildings

The factors affecting the environmental sustainability of buildings are multifaceted and have become a significant focus in the construction industry due to growing concerns about the negative impacts of human activities on the environment. Studies in the United States indicate a substantial market demand for sustainable buildings; however, sustainable building retrofit projects are not as widely pursued. This is due to several reasons, including a lack of information about the building and its systems after the design phase[76], reluctant stakeholder commitment due to insufficient energy cost incentives, and perceptions that sustainable practices are not cost-effective[77]

In developing countries like Nigeria, there is a low level of awareness regarding sustainability. Educating construction participants on sustainability concepts is essential to improve understanding and achieve holistic sustainability [78]. Research has shown that most construction stakeholders in Nigeria perceive the social dimension of sustainability as the most important objective in delivering sustainable construction [79]. However, the understanding and implementation of sustainability in the construction industry remain piecemeal and unstructured [79].

Building stakeholders, including owners, tenants, investors, building operators, and designers, often have conflicting perspectives on sustainable retrofitting. For instance, owners might be motivated by reduced lifecycle costs and increased return on investment, while tenants may seek incentives like lower rent or increased productivity [80].

Studies indicate a need to promote the activities of users and government regulatory agencies in sustainable residential property development, as these stakeholders significantly influence development decisions7. Financial constraints, lack of skilled personnel, low coordination between institutions, and limited community awareness have hindered the use and management of green spaces. Improving the legal framework, enhancing public participation, and strengthening urban green space management are crucial measures to improve usability in urban areas of Ethiopia[81, 82].

In Addis Ababa, constraints and opportunities in applying green building principles have been identified. Many buildings have poor indoor quality, rely on imported materials, consume unnecessary energy, and consider water efficiency or the surrounding area. Challenges include a lack of awareness about green buildings, lack of interest from developers, and absence of government incentives. Public awareness campaigns are recommended as the best strategy to promote green buildings[81]

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter describes in detail the methodology used in gathering the information necessary in this study. Its step was elaborated in detail and carried out systematically to achieve a high description of the study area, research design, and sources of data, including the sampling plan and data analysis method and also the degree of reliability.

3.1. Description of the Study Area

The selected site for the study of sustainability of building construction project was found in Woliso town because the construction of several buildings is rapidly changing in town. Woliso is the capital of the Southwest Shewa Zone in the Oromia region, located on the Addis Ababa– Jimma Road, approximately 114 km southwest of the capital. Woliso has a population of 61,140, according to the 2007 census conducted by the Central Statistics Authority of Ethiopia. However, the municipality estimates that the actual figure is now closer to 100,000. There are seven officially recognized kebeles (administrative divisions or woredas). The town is served by two hospitals, fifteen health clinics, and two health stations. It hosts a faculty of Social Science campus under Ambo University and three private colleges. Woliso has seven hotels, and the town's main economic activities are commerce, tourism, and manufacturing (**Figure 3.1**)

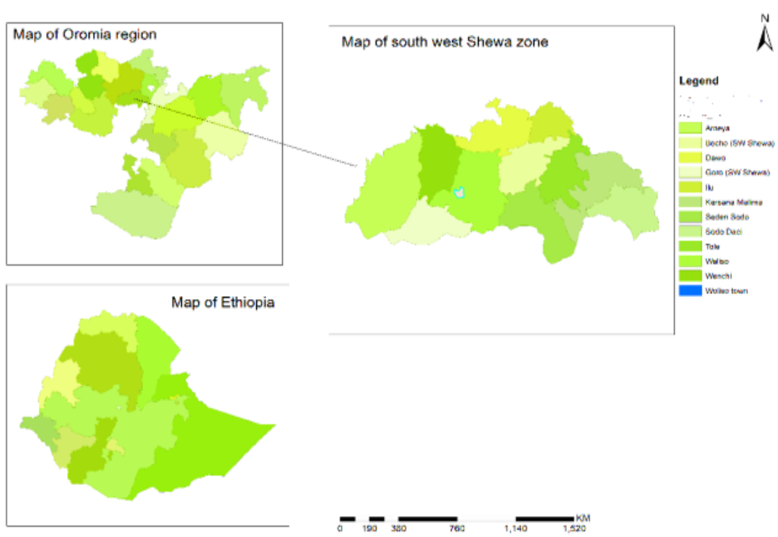

Figure 3.1. Map of the study setting [This map was drawn by the author using ArcGIS software (ArcGIS_Desktop_10.7.1.11595)]

3.2. Research Design

The study employed mixed methods (quantitative and qualitative) design to assess the environmental sustainability of building construction in Woliso town. There were different types of survey research designs used in this study; the first was a cross-sectional type of survey whereby different groups of people who differ in the variable of interest but share other characteristics were asked questions about their experience on environmental sustainability issue related to building construction. It used this method to perform a detailed study on the selected buildings for understanding the existing situations in terms of green practices based on standardized measurement, which is LEED. Based on the definition, selection criteria for appropriate recent buildings are developed to review based on LEED credit, to determine its gaps and potential, and to recommend appropriate measures. The study buildings were selected according to the following criteria:

Table 3.1 Selection criteria for study building

Function	Mixed Use Building
Age	Built buildings with an age of not more than 15 years
Location	Located along the transportation route
Accessibility	Easy access and the number of people who access it

3.3. Study Variables

3.3.1. Dependent Variables

Environmental sustainability of buildings construction, which was measured in the following criteria (**Table 3.2**).

Table 3.2: Dependent variables of the study

The main dependent variable measuring indicators	Heat island effect
	Energy-efficient equipment
	Natural lightning and ventilation
	Innovative wastewater technology
	Water use reduction

3.3.2. Independent variables

- Socio-demographic characteristics of the respondents
- Function of the building
- Age of the building
- Location of the building
- Accessibility of the building

Here's how they influence each other:

Socio-Demographic Characteristics

- Respondents' awareness or income levels may influence the adoption of technologies like energy-efficient equipment or wastewater systems.

Function of the Building

- The function of the building can affect the water and energy efficiency. For example, residential buildings might emphasize water conservation more, while industrial ones focus on energy efficiency and wastewater technologies.

Age of the Building

- Older buildings may lack modern features (e.g., energy-efficient equipment or innovative wastewater systems), potentially worsening sustainability indicators.

Location of the Building

- Urban areas often face higher heat island effects, increasing the need for energy efficiency and natural ventilation. Rural locations might focus more on water use reduction.

Accessibility of the Building

- Easy access to resources might facilitate the implementation of sustainable solutions like energy-efficient systems and advanced wastewater technologies.

3.4. Sample Size and Sampling Technique

The population for this study consists of construction stakeholders, environmental protection officers, building owners, and tenants in Woliso town. Given the study’s focus on assessing environmental sustainability in building construction, based on the LEED criteria. The primary study participants were tenants using or living in the selected buildings. Considering the daily habits of the tenants in relation with green building in the study as 50% (as no prior study was conducted in the setting), the sample size considered single proportion formula.

$$n = \frac{Z^2 \cdot p \cdot (1-p)}{E^2}$$

where:

- n is the sample size.
- Z is the Z-value corresponding to the desired confidence level
- p is the estimated proportion of the population.
- E is the margin of error.

$$n = \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{(0.05)^2}$$

$$n = \frac{3.8416 \times 0.25}{0.0025}$$

$$n = \frac{0.9604}{0.0025} = 384.16$$

Since the total sample in the study area was less than 10,000, the correction formula was used to calculate the final minimum sample size. The average tenants living or working in a single building was 20, which gave a total Sample size of (N=200) tenants in selected buildings.

$$n_{adj} = \frac{n}{1+\frac{n-1}{N}}$$

where:

- n_{adj} is the adjusted sample size.
- n is the initial sample size calculated using the formula above.
- N is the population size.

$$n_{adj} = \frac{384}{1+\frac{384-1}{200}}$$

$$n_{adj} = \frac{384}{1+\frac{383}{200}}$$

$$n_{adj} = \frac{384}{1+1.915}$$

$$= \frac{384}{2.915}$$

$$n_{adj} \approx 132$$

Therefore, the total minimum sample size of the tenants included in the study was 132. The study participants were included using a random sampling technique. Moreover, 24 key informants [ten (10) building owners or facility managers, five (5) environmental protection officers and nine (9) construction stakeholders] were included to evaluate their awareness, provision insights into sustainability regulations, and the knowledge and practical applications of sustainability principles. Purposive sampling techniques were used to collect data from key informants who play a crucial role in or are directly affected by sustainable building practices, thereby enhancing the depth and relevance of the research findings in the Woliso building construction.

3.5. Data sources and types

This data was gathered using the primary data from questionnaires, observation, and in-depth interviews from key informants to gain more information about the selected buildings' situations.

3.6. Data collection tool

To obtain a comprehensive understanding of the experiences and actual effects of existing building with respects to green building design, this study used data collection methods (questionnaires, observation, and interviews) with the owner, tenant, environmental protection office, and construction office managers. This study employed observations of the physical characteristics of the selected buildings' environment and surroundings.

3.7. Data Analysis and Presentation

The data were analyzed by quantitative and qualitative data analysis methods. Quantitative analysis was used to generate descriptive statistics to analyze frequencies and percentages. The qualitative measure was used to summarize key findings and explanations through thematic analysis and coding. Statistical Software for Social Science (SPSS) version 23 was used for quantitative analysis and Nvivo was used for qualitative analysis. The data were presented in the form of graphs, tables, and text format. Selected buildings illustrated using aerial photographs, pictures, maps, and descriptive words present the existing situation.

3.8. Reliability and Validity of the Data

The data was analyzed using statistical software to ensure the accuracy and reliability of the results. Therefore the reliability of the questionnaire was tested using Cronbach's alpha test. This method measures the reliability of the questionnaire by comparing each field with the mean of all fields. The normal range of Cronbach's alpha value is between 0.0 and 1.0, with higher values indicating a higher degree of internal consistency. Cronbach's alpha value of 0.804 was derived from the assessed criteria, as shown in table 3.3. This indicates that the instrument is reliable, as the degree of reliability of an instrument increases as the value approaches 1.0.

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

Where:

- N is the number of items.
- $\bar{c}$ is the average covariance between item pairs.
- $\bar{v}$ is the average variance of each item.

Table 3.3: Reliability and Validity of the Data

Reliability Statistics	
Cronbach's Alpha	N of Items
0.804	19

3.9. Ethical Considerations

Before starting data collection, ethical approval was obtained from the Ethical Review Board (ERB) of Jimma Institute of Technology, Jimma University. Then, the selected administrative offices in Woliso town were contacted via a formal letter from the Jimma Institute of Technology. The purpose, objectives, use, and benefits of the study were explicitly explained to all respondents, and their informed written consent was obtained before the interview session. The confidentiality of each respondent's identity was assured and ensured throughout the process of documentation by reporting.

CHAPTER FOUR

RESULT AND DISCUSSIONS

This chapter presents the findings of the study, which were based on primary data collected from respondents through questionnaires, interviews, and observation guides. The assessment aimed to provide a comprehensive understanding of the characteristics of buildings and facilitate easy comparisons. The thematic topics or criteria are used to compare the assessed buildings in terms of heat island effect, indoor environment quality, energy consumption, and water consumption. A critical analysis of each objective was conducted, and inferences and conclusions were drawn based on the data obtained. The findings are presented in topic areas and sub-sections that cover environmental sustainability of building construction, awareness, knowledge, and practice considerations, as well as factors that affect environmental sustainability in building construction. The chapter concludes with a discussion of the implications of the findings for achieving environmental sustainability in building construction.

4.1. Socio-demographic characteristics of the respondents

Given the scope of data collection from multiple sources, it was deemed necessary to present the collected data in a structured and organized manner. As such, the first step in presenting the data was to provide an overview of the demographics of the respondents. Out of a total of 132 tenants approached for data collection, 130 answered the question, resulting in a response rate of [98.5%; 130/132]. As shown in **Table 4.1**, out of the total respondents who participated in the study, there were 63 (40.9%) females and 91 (59.1%) males. The gender distribution in your study allows for a nuanced analysis of how men and women perceive, experience, and influence environmental sustainability in building construction. In terms of age distribution, the majority of participants (73.78%) fall within the age range of 18-30 years. This demographic may have differing perspectives on environmental sustainability compared to older generations, as younger people are generally more environmentally conscious. By understanding the age distribution, you can better interpret how different age groups might perceive the factors affecting sustainability—such as resource use, energy efficiency, and green building materials. The small proportion of older participants (over 46 years) may have different priorities or approaches to sustainability in construction, and this generational perspective could reveal valuable insights into the challenges of implementing sustainable practices across different age groups. The fact that a majority of respondents (61.2%) hold a degree or above is important because education is often closely linked to an individual's knowledge of sustainability practices. Construction stakeholders, environmental protection officers, and owners are likely to have some form of higher education, which might influence their understanding and implementation of sustainable building practices. The educational status of the respondents allows you to cross-analyze if those with higher educational qualifications have more sustainable practices or knowledge. Lastly, in terms of profile, with a small proportion being construction stakeholders (5.8%) owner or manager of the building (6.5%) and environmental protection officials (3.3%). Their involvement is crucial because they are directly involved in decision-making processes related to building sustainability. Their input will highlight factors such as financial constraints, policy barriers, and the technical feasibility of implementing sustainable practices in the construction industry.

Table 4.1. Socio-demographic characteristics of the respondents

Variable	**Category**	**Frequency**	**Percentage**
Gender	Male	91	59.09
	Female	63	40.9
Age (years)	18-30	105	68.18
	31–45	32	20.8
	≥46	17	11.04
Educational status	Diploma	33	21.43
	Degree	65	42.21
	Above degree	56	36.4
Study participants profile	Tenants	130	84.4
	Owners/Facility manager	10	6.5
	Environmental protection bureau officials	5	3.3
	Construction stakeholders	9	5.8

4.2. Tenant daily habit on the existing situation of selected buildings

In this section, a detailed analysis and description of the 10 selected buildings were conducted based on the principles outlined in the Leadership in Energy and Environmental Design (LEED) criterion. The evaluation focused on various aspects such as energy efficiency, sustainable materials, water conservation, indoor environmental quality, and innovation in design. Each building was assessed against the specific criteria set forth by LEED to determine its level of compliance and performance in promoting environmentally friendly and energy-efficient practices. The findings from this analysis provide valuable insights into the sustainability and green building features of the selected buildings, highlighting their contributions towards creating healthier and more sustainable built environments.

4.2.1. Urban Heat Island Effect

The Urban Heat Island (UHI) effect occurs when urban areas experience significantly higher temperatures than surrounding rural or less-developed areas. This phenomenon results from increased heat absorption by buildings, roads, and other infrastructure, coupled with reduced vegetation. This report analyzes survey findings concerning thermal comfort, ventilation, and heat mitigation measures in alignment with LEED criteria. The survey results reveal that a significant majority (86.2%) of respondents have access to windows or openings that can be used for natural ventilation, which helps reduce reliance on mechanical cooling systems. However, over half of the respondents (51.5%) experience discomfort due to high temperatures inside or outside the building, indicating issues with heat retention likely caused by urban warming and material choices. Additionally, 50.8% of respondents noted that specific areas within their units feel hotter than others, emphasizing the need for improved insulation and airflow solutions. On a positive note, 60.8% of respondents reported the presence of vegetation or shading devices around their buildings, which help mitigate the Urban Heat Island (UHI) effect. Nevertheless, 39.2% still lack adequate greenery and shading solutions, suggesting that expanding tree coverage, using reflective surfaces, and enhancing passive cooling strategies could significantly improve both indoor and outdoor thermal conditions (**Table 4.2**.)

Table 4.2: Tenants' daily habits on existing buildings parameters of the Urban Heat Island Effect

Questions	**Yes, n (%)**	**No, n (%)**
Q1: Access to windows or openings that can be used for natural ventilation.	52 (40)	78 (60)
Q2: Discomfort due to high temperatures inside or outside the building (e.g., heat, humidity) compared to nearby areas, such as streets or open spaces.	67 (51.5)	54 (48.5)
Q3: Specific areas in your unit feel hotter than others.	66 (50.8)	64 (49.2)
Q4: Any measures to mitigate heat vegetation (e.g., green roofs, trees, or shrubs) other shading devices around your building.	79 (60.8)	51 (39.2)

4.2.2. Water Efficiency

The survey highlights significant gaps in water efficiency and conservation practices. Only 20% of respondents use water-efficient appliances and fixtures, underscoring the need for more widespread adoption of low-flow faucets, showerheads, and ENERGY STAR appliances to reduce potable water consumption. Furthermore, 61.5% of respondents rely on tap water for both indoor and outdoor activities, highlighting the importance of alternative water sources such as rainwater harvesting and graywater reuse. While 42.3% of respondents use dual-flush or low-flow toilets, there is still considerable potential for high-efficiency plumbing fixtures to minimize water waste. Notably, none of the respondents currently recycle water, pointing to the need for on-site water treatment and reuse systems. Additionally, only 20% of respondents have water metering systems installed, which are essential for monitoring, managing, and optimizing water use. To meet LEED standards, it is crucial to adopt high-efficiency fixtures, alternative water sources, and smart monitoring systems for sustainable water management and conservation (**Table 4.3**).

Table 4.3: Tenants' daily habits on existing buildings parameters of Water Efficiency

Questions	**Yes, n (%)**	**No, n (%)**
Q1: Use of water-efficient appliances and fixtures in your unit and building.	26 (20)	104 (80)
Q2: Use of tap water for indoor and outdoor water consumptions activity.	80 (61.5)	50 (38.5)
Q3: Use of Dual flush or low flow toilet.	55 (42.3)	75 (57.7)
Q4: Recycling water.	0	130(100)
Q5: Water Metering systems installed to monitor and control water consumption.	26 (20)	104(80)

4.2.3. Energy Efficiency

The survey results provide valuable insights into energy efficiency and sustainability practices within building units. A significant proportion of respondents (68.5%) reported having energy-efficient equipment installed in their units, such as appliances and lighting, suggesting that energy-saving measures are becoming more common. However, 31.5% of respondents still lack such upgrades, indicating room for improvement in promoting energy-efficient technologies. When asked about their daily lighting habits, 72.3% of respondents rely on artificial lighting, reflecting the need for greater optimization of natural lighting in buildings to reduce energy consumption. In terms of building infrastructure, 70.8% of respondents confirmed that their buildings are equipped with energy-efficient units, while 29.2% indicated that their buildings lack such systems. This highlights the growing trend toward energy-efficient buildings but also points to the need for further retrofitting efforts in older buildings. However, 60% of participants noted that certain areas in their buildings lack sufficient natural light, which could lead to increased reliance on artificial lighting, contributing to higher energy consumption. Renewable energy usage remains limited, with only 20% of respondents utilizing renewable energy sources, presenting a substantial opportunity to incorporate more sustainable energy solutions, such as solar or wind power, to reduce reliance on conventional energy grids.

Regarding lighting efficiency, 63.8% of respondents reported using energy-efficient lamps, indicating that many individuals are making efforts to reduce their energy usage. However, 36.2% still rely on less efficient lighting, representing another area for potential energy savings. In terms of cooling, 36.2% of respondents use mechanical systems to cool their homes during hot seasons, while 63.8% either rely on natural ventilation or do not have cooling systems in place. This suggests that some building units may benefit from energy-efficient cooling solutions to improve comfort and reduce energy costs. Additionally, 32.3% of respondents indicated using other sources of energy, such as generators or alternative energy solutions, while the majority still rely on traditional energy sources. Overall, the survey highlights areas of strength in energy-efficient practices, such as the use of energy-efficient units and lamps. However, there is a significant opportunity to improve the adoption of renewable energy, increase natural lighting, and enhance energy-efficient cooling systems to further reduce energy consumption and promote sustainability in building units (**Table 4.4**).

Table 4.4: Tenants' daily habits on existing buildings parameters of Energy Efficiency

Questions	Yes**, n (%)**	No**, n (%)**
Q1: Energy-efficient equipment installed in your unit (e.g., appliances, lighting).	41(31.5)	89(68.5)
Q2: Usage of artificial lighting in daily activities.	94(72.3)	36(27.7)
Q3: Energy efficient units in the buildings.	92(70.8)	38(29.2)
Q4: Areas that lack sufficient natural light the buildings	78 (60)	52(40)
Q5: Use of renewable energy.	26(20)	104(80)
Q6: Use energy efficient lamps.	83(63.8)	47(36.2)
Q7: Use a mechanical system to cool your house during hot seasons.	47(36.2)	83(63.8)
Q8: Other source of energy used in your building	42(32.3)	88 (67.7)

4.2.4. Indoor Environmental Quality

The survey findings related to discomfort issues regarding lighting or ventilation show that 73.1% of respondents have experienced discomfort due to these factors. This is a significant finding, as it highlights the potential for improvements in the indoor environment that could impact on the comfort, health, and well-being of building occupants. Additionally, a significant majority (86.2%) of respondent's experience discomfort related to thermal comfort, emphasizing the need for better temperature regulation within buildings to enhance occupant comfort (**Table 4.5**)

Tabel 4.5: Tenants' daily habits on existing buildings parameters of Indoor Environmental Quality

Questions	**Yes, n (%)**	**No, n (%)**
Q1: Discomfort issues related to lighting or ventilation that you have experienced.	95 (73.1)	35 (26.9)
Q2: Discomfort thermal effect	112 (86.2)	18 (13.8)

4.3. Physical Assessment of the Existing Situation of Selected Buildings

In line with the tenants' response on their daily habits, the physical assessments of the existing situation of selected buildings were conducted by the researchers as per the selected LEED criteria and the detailed description and evaluation were presented as follows.

4.3.1. Building 1: Cooperative Bank of Oromia (Coop Bank)

A. Building's Purpose and Description

Its location is indicated as the main route that leads from Addis Ababa to Jimma. The ownership title of the building is held by the Cooperative Bank of Oromia and is located in Woliso town. The building serves a multipurpose function and has an area of 1500 m2 and has five floors. It is relatively new; with an age of two years. The COOP building features open floor plans, effective circulation routes, and suitable space zoning that maximize the benefits of natural lighting and ventilation. There is only one staircase in this building, and there is a wide hallway for horizontal movement for building occupants or tenants. Despite the fact that each floor has a fire extinguisher installed, there are no fire escape stairs. The structure contains an underground parking place for cars. The building serves as a bank, different government offices, gymnasium, meeting hall and restaurant.

Figure 4.1. Satellite map of the Cooperative Bank of Oromia (Source: Google map).

4.3.1.1. Urban Heat Island Effect

The building does not have a green roof. The cooperative bank of Oromia building took almost its entire plot and has open spaces in the front parts of the building, but the outdoor area had no vegetation or did not have access to green plants around the building areas and there are no potted plants on all the balconies and around the entrance. The COOP building has Shading devices (overhangs) that can help to control the amount of sunlight entering the building and prevent excessive heat gain


.

Figure 4.2. Externals spaces of the COOP building (source by Author, 2023).

4.3.1.2. Water Efficiency

A. Innovative Wastewater Technology and Water Use Reduction

In COOP building, there was no significant water-saving technology or practices currently implemented in the building, as the focus on water conservation is lacking. No water-efficient fixture metering exists that helps water management and identify opportunities for additional water savings. During rainy season rainwater from the roof passes through the downpipes to the main drainage line without restoration. Municipal water is the main source of water for indoor and outdoor use, such as toilet flushing, cleaning, and others, with one 10,000-liter tankers in case of water loss. Monitoring and managing water consumption at both the individual and building levels are not actively practiced. The building has not implemented any wastewater treatment. Nothing is done to recycle or reuse rainwater and wastewater, potentially leading to inefficiencies in water treatment processes.

4.3.1.3. Energy Efficiency

A. Energy-Efficient Equipment, Natural Lightning, and Ventilation

Electricity is the main source of energy for different activities like computers and light bulbs are used the most. LED and fluorescent lights make up the majority of the light bulbs used in the building. Users may not be aware of specific energy-efficient equipment in their units since there is no mention of such installations. From data collected during site observation, it was observed that the building has enough windows that provide sufficient light for the interior part of the building and stairways, even though some of the windows are covered by curtains that hinder the entrance of light, forcing the users to use artificial light during the daytime. Users could express high satisfaction with natural lighting in their units, but they are not conscious of their energy consumption habits, such as turning off lights and utilizing natural lighting. Discomfort issues related to lighting or ventilation is minimal or absent due to the reliance on natural elements. Because in this building, there is properly designed operable windows that allow for natural airflow and ventilation, reducing the dependence on mechanical cooling systems. In COOP bank building nothing exists as tracking energy use, management for energy performance, and renewable energy usage in the building that promotes continuity of information to ensure that energy-efficient operating strategies are maintained.

Figure 4.3. Artificial lights used carelessly during day (Source by Author, 2023)

4.3.1.4. Indoor Environmental Quality (IEQ)

A. Indoor and Outdoor Space Design for Visual Comfort and Aesthetics

From data collected, natural ventilation was effective, and air circulation is adequate. The ambient noise level of COOP building is noisy. A source of noise disturbance that affects their comfort was from the busy street outside of the building, because there are not enough trees to protect such problems, and the interior acoustics were not a problem.

4.3.2. Building 2: Woliso Town Administrative Building

A. Building's Purpose and Description

Its location is indicated as the main route that leads from Addis Ababa to Jimma. The building is owned by the Woliso town planning office and is in the town of Woliso. It serves as an office and has an area of 900 m^2. It is a building built thirteen years ago and has four floors. Stairs used for regular circulation for the tenants or users of the building with an open corridor for horizontal circulation. There is no fire escape stairs even if fire extinguishers are installed on every floor. The building has enough backyard parking spaces. The building is occupied by different government offices such as town construction offices, land management offices, sanitation and green development group and mayor offices, office of trade and revenue registration, business registration and license system office, furniture room and saving credit corporation office and office of finance and procurement for property management.

Figure 4.4: Town Administrative Building fire extinguisher equipment backyard parking space (source by author, 2023)

4.3.2.1. Urban Heat Island Effect

The Woliso town administrative building has open green spaces surrounding it. In spite of enough trees and plants around the building, there were no potted plants in all the balconies and entrances of buildings that minimize the effects of microclimates to create a healthy living environment for tenants, users, and the town. The building does not have a green roof. There is a reflective coating like a cobblestone used around the building in the parking area. To reduce the absorption of solar heat gain from the external surface, the building has a curtain as shading devices.

Figure 4.5. Town Administrative Building external spaces and open green areas (Source by Author, 2023)

4.3.2.2. Water Efficiency

A. Innovative Wastewater Technology and Water Use Reduction.

There are currently no notable water-saving devices or practices at the Woliso Town Administrative Office Building since there is little emphasis on water conservation. No water-efficient fixture metering exists that helps water management and identify opportunities for additional water savings. Municipal water is the main source of water for all indoor and outdoor water used in the building even if the building does not have toilets and water. They use toilets and water outside the building. Moreover, there is no restoration of rainwater and recycling or reuse of wastewater; instead, it passes through the main drainage line.

4.3.2.3. Energy efficiency

A. Energy-Efficient Equipment, Natural Lightning, and Ventilation

In Woliso town administrative office building, electricity is the main source of energy for different activities; computers and light bulbs are used the most. Bulb and LED lights make up the majority of the light bulbs used in the building. Users may not be aware of specific energy-efficient equipment in their units since there is no mention of such installations. During site observation, it was observed that the building has enough windows that provide sufficient light for the interior part of the building and stairways. Users could express high satisfaction with natural lighting in their units, therefore Artificial light not used during the day. Discomfort issues related to lighting or ventilation is absent due to the reliance on natural elements. Because in this building, there are properly designed operable windows that allow for natural airflow and ventilation, reducing the dependence on mechanical cooling systems. In this building nothing exists as tracking energy use, management for energy performance, and renewable energy usage in the building that promotes continuity of information to ensure that energy-efficient operating strategies are maintained.

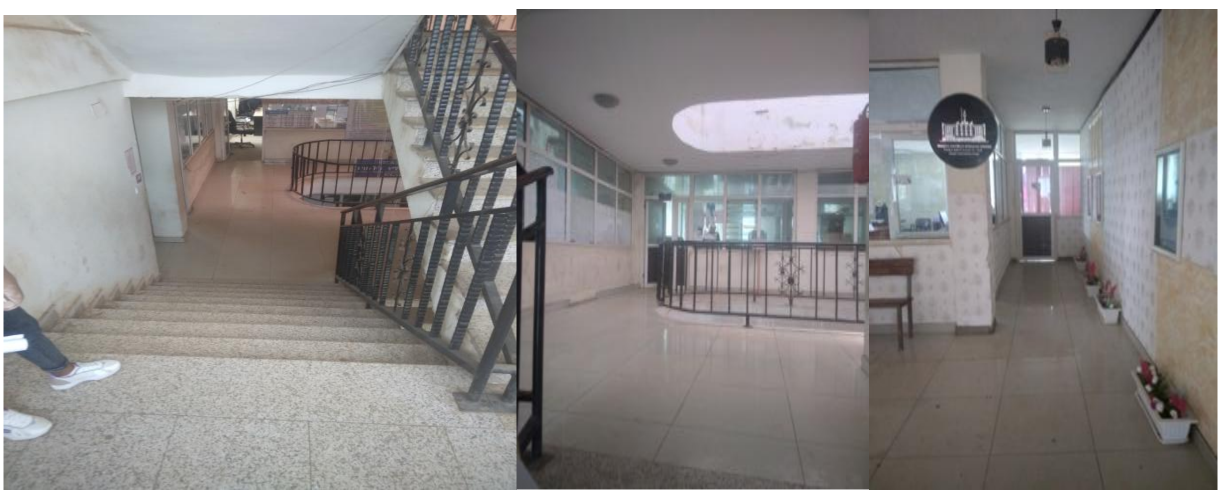

Figure 4.6. Town Administrative Building natural lighting and ventilation (Source by Author, 2023)

4.3.2.4. Indoor Environmental Quality (IEQ)

A. Indoor and Outdoor Space Design for Visual Comfort and Esthetics

From data collected the interior temperature is normal and natural ventilation was effective, and air circulation is adequate. Despite its location, the ambient noise level of administrative office buildings is moderate. There are enough trees around the building to go between noise and air quality for this building that creates a sense of calm and connection to the surrounding and the building concerning its acoustics is good.

4.3.3. Building 3: Haro Wonchi Building

A. Building's Purpose and Description

The building, located on the main road from Addis Ababa to Jimma, is privately owned and centrally situated in town. It is a multipurpose structure with six floors and an area of 600m², and it is eleven years old. The building has one main stair for regular circulation and open corridors for horizontal movement, with a fire escape stair up to the second floor. It features a backyard parking space but no front space. The building houses banks, offices, a bakery, cafeterias, a hotel, and a guest house.

Figure 4.7. Haro Wonchi building (source: Google map)

4.3.3.1. Urban Heat Island Effect

Haro Wonchi building has no open space at the front part besides the back of the building which is paved with tiles for parking purposes. The building does not have a green roof. There are some green areas within the building's plot, with planted trees in the surroundings around the parks that provide shade. There are potted plants in the entire stair landing and around the entrance that minimize the effects on microclimates, tenants, and users. There is no reflective coating used in front of the building to reduce the absorption of solar heat gain from the external surface except tiles paved in the parking area, the building has no overhangs as shading devices.

Figure 4.8. Pavement, surrounding trees, parking, and open space (Source by Author, 2023)

4.3.3.2. Water Efficiency

A. Innovative Wastewater Technology and Water Use Reduction

In Haro Wonchi building, there was no reduction in pressure on freshwater resources. Tap water was the main source of water for indoor and outdoor activities in buildings with two 5,000-liter tankers in case of water loss. Water-efficient fixtures are installed. During rainy season rainwater from the roof passes through the downpipes to the main drainage line without restoration. There were no wastewater treatments. Rainwater and gray water pass through the downpipes to the main drainage line without being recycled or reused. Monitoring and managing water consumption at both the individual and building levels are not actively practiced.

4.3.3.3. Energy Efficiency

A. Energy-Efficient Equipment, Natural Lightning, and Ventilation

During site observation, it was observed that the building has enough windows that provide sufficient light for the interior part of the building and stairways, even though some of the windows are covered by curtains that hinder the entrance of light, forcing the users to use artificial light during the daytime. In Haro Wonchi building electricity is the main source of energy for different activities like water heating, cooking, barista, computers, and light bulbs. LED and fluorescent lights make up the majority of the light bulbs used in the building. Air conditioners and fans are used at the ground floor. Artificial light is not used in all parts of the rooms during the day, except the ground and first floor that is due to the window are covered by advertising paper. In the building nothing exists as tracking energy use, management for energy performance, and renewable energy usage in the building that promotes continuity of information to ensure that energy-efficient operating strategies are maintained.

Figure 4.9. Haro Wonchi Building natural lighting and ventilation (Source by Author, 2023)

4.3.3.4. Indoor Environmental Quality (IEQ)

A. Indoor and Outdoor Space Design for Visual Comfort and Esthetics

Based on the data collected, the interior temperature is normal, natural ventilation is effective, and air circulation feels adequate. The Haro Wonchi building is situated a few meters from the main road, experiencing noise pollution from high vehicular traffic. The building lacks protection from internal noise, leading to exposure to varying noise levels due to insufficient trees.

4.3.4. Building 4: Southwest Shewa Zone Administration Office

A. Building's Purpose and Description

The main road that goes from Addis Ababa to Jimma defines this building’s location. The ownership title of the building is southwest Shewa administrations offices and is located in Woliso town. The building has an office and an area of 800 m^2 and has four floors. It is relatively a recent building, with an age of seven years. The building has stairs and ramps for regular circulation and a corridor for horizontal circulation. The building has enough backyard and front space for parking. Functionally the building serves different government sectors as insurance corporations, southwest Shewa human resources offices, youth, and sport offices, southwest Shewa zone administration offices, southwest Shewa zone construction offices, management offices and a store.

Figure 4.10. Southwest Shewa administration offices (source: Google Maps and by Author, 2023 respectively)

4.3.4.1. Urban Heat Island Effect

Southwest Shewa zone administrative building has open spaces but no green plant surrounding the building. The building does not have a green roof. There are no shading devices, such as overhangs that can help control the amount of sunlight entering the building and prevent excessive heat gain. There are no urban heat management strategies, such as cool corridors, green infrastructure, and proper ventilation systems in all balconies and around the entrance that can help combat excessive heat in densely populated areas. There is no pavement or stone paved around the building; it is covered by gravel up to the walkways.

Figure 4.11. Pavement, parking, and open space of southwest Shewa zone administrative building (Source by Author, 2023)

4.3.4.2. Water Efficiency

A. Innovative Wastewater Technology and Water Use Reduction

In the Southwest Shewa zone administrative building, there are no significant water-saving technologies or practices currently in place. The focus on water conservation is lacking, with no water-efficient fixture metering or efficient fixtures. Rainwater from the roof flows through downpipes to the main drainage line without restoration during the rainy season. Municipal water is the main source for indoor and outdoor use, with one 10,000-liter tank in case of water loss. Monitoring and managing water consumption at both individual and building levels are not actively practiced, and there is no wastewater treatment system in place.

4.3.4.3. Energy Efficiency

A. Energy-Efficient Equipment, Natural Lightning, and Ventilation

In the Southwest Shewa zone administrative building, electricity is the primary energy source for various activities, with computers and light bulbs being the most used. LED and fluorescent lights are predominantly used in the building. The building has ample windows providing natural light, but some are covered by curtains, necessitating artificial lighting during the day. Ventilation issues arise due to small rooms accommodating a high number of people. There is no tracking of energy use, management for energy performance, or utilization of renewable energy sources to ensure the continuity of energy-efficient practices in the building.

Figure 4.12. Southwest Shewa zone administration building natural lighting and ventilation (Source by Author, 2023)

4.3.4.4. Indoor Environmental Quality (IEQ)

A. Indoor and Outdoor Space Design for Visual Comfort and Esthetics

Based on the data collected, natural ventilation was ineffective, and air circulation relies on the mechanical cooling system. The ambient noise level in the building is moderate. A source of noise disturbance affecting comfort is the busy street outside due to a lack of trees to mitigate the issue.

4.3.5. Building 5: Teka Building

A. Building's Purpose and Description

Its location is indicated as the main route that leads from Addis Ababa to Jimma. It is privately owned and situated in town center, serving multiple purposes with an area of $400m^2$ across four floors. The building is relatively with an age of fourteen years. And has stairs for circulation and open corridors for horizontal movement. There are fire escape stairs and fire extinguishers. Backyard parking is available, but there is no front space. Functionally the building serves for banks, shops, laundry facilities, private agency offices, microfinance institutions, game zones, and restaurants.

Figure 4.13. Teka building exterior environment (Source by Author, 2023)

4.3.5.1. Urban Heat Island Effect

The Teka building has small open spaces in the front parts of the building but enough space at the back. However, there are no potted plants in all the balconies but around the entrance there were green plants that minimize the effects of microclimates for tenants, users, and the environment. The building does not have a green roof even. The building's footprint is the stone-paved at the front. There is no use of overhangs that can help control the amount of sunlight entering the building and prevent excessive heat gain. There are no urban heat management strategies, such as cool corridors and green infrastructure.

Figure 4.14.Cool pavement, surrounding trees, parking, and open space (Source by Author, 2023)

4.3.5.2. Water Efficiency

A. Innovative Wastewater Technology and Water Use Reduction

In Teka building, there were no any significant water-saving technologies or practices currently implemented in the building, as the focus on water conservation is lacking. No water-efficient fixture metering exists that helps water management and identify opportunities for additional water savings. During rainy season rainwater from the roof passes through the downpipes to the main drainage line without restoration. Municipal water is the main source of water for indoor and outdoor use, such as toilet flushing, cleaning, and others, with one 5000-liter tankers in case of water loss. Monitoring and managing water consumption at both the individual and building levels are not actively practiced. The building has not implemented any wastewater treatment. Nothing is done to recycle or reuse rainwater and wastewater, potentially leading to inefficiencies in water treatment processes.

4.3.5.3. Energy Efficiency

A. Energy-Efficient Equipment, Natural Lightning, and Ventilation

In Teka building only electricity is the main source of energy for different activities; computers and light bulbs are used the most. Fluorescent lights and bulb make up the majority of the light bulbs used in the building. Users may not be aware of specific energy-efficient equipment in their units since there is no mention of such installations. From data collected during site observation, it was observed that the building has enough windows that provide sufficient light for the interior part of the building and stairways, even though some of the windows are covered by curtains that hinder the entrance of light, forcing the users to use artificial light during the daytime. Users could express some satisfaction with natural lighting in their units, but they are not conscious of their energy consumption habits, such as turning off lights and utilizing natural lighting. There is discomfort issues related to ventilation.

Figure 4.15. Teka Building natural lighting and ventilation (Source by Author, 2023)

4.3.5.4. Indoor Environmental Quality (IEQ)

A. Indoor and Outdoor Space Design for Visual Comfort and Esthetics

From data collected natural ventilation was ineffective and air circulation is not adequate. The Ambient noise level of building is noisy. Lack of dedicated space for parking, the existence of public service provider offices, and the building’s location create a noisy environment for the tenants or users of the building.

4.3.6. Building 6: Woliso Woreda Administration Building

A. Building's Purpose and Description

Its location is indicated as the main route that leads from Addis Ababa to Jimma. The building is owned by the Woliso woreda finance office and is located in the town of Woliso. The building serves as an office and has an area of 900 m2 and has five floors. It is a modern building built three years ago. The building has open floor plans, efficient circulation paths, and appropriate zoning of spaces to optimize natural lighting and ventilation opportunities. This building has two stairs for regular circulation for the tenants or users of the building with a very open corridor for horizontal circulation. Fire extinguisher is installed on every floor. The building has no ground or backyard parking space except for a small space in the front part. Functionally, the building from the ground floor up to the last floor is occupied by different government offices.

Figure 4.16. Map of the Woliso Woreda administration offices (Source from Google map and Author)

4.3.6.1. Urban Heat Island Effect

The Woliso woreda finance office building has open spaces in the front parts of the building, but the outdoor area has no vegetation or does not have access to green plants around the building areas. The building does not have a green roof. There is no reflective coating or cool pavements around the building. The building had no Shading devices (overhangs) that can help to control the amount of sunlight entering the building and prevent excessive heat gain. Additionally, there are no potted plants in all the balconies and around the entrance that minimizes the effects of microclimates to create a healthy living environment for tenants, users, and the town.

Figure 4.17. Pavement, parking, and open space of Woliso woreda administration building (Source by Author, 2023)

4.3.6.2. Water Efficiency

A. Innovative Wastewater Technology and Water Use Reduction

In Woliso woreda finance office building, there were not any significant water-saving technologies. In spite of water-efficient fixtures and fittings, such as low-flow toilets that use less water wasted during daily activities installed on every floor, they use water and toilet outside the building. During rainy season rainwater from the roof passes through the downpipes to the main drainage line without restoration. Municipal water is the main source of water for indoor and outdoor use, such as cleaning, and others, with one 5,000-liter tankers in case of water loss. Monitoring and managing water consumption at both the individual are not actively practiced. The building has not implemented any wastewater treatment. Nothing is done to recycle or reuse rainwater and wastewater, potentially leading to inefficiencies in water treatment processes.

4.3.6.3. Energy Efficiency

A. Energy-Efficient Equipment, Natural Lightning, and Ventilation

Electricity is the main source of energy for different activities; computers and light bulbs are used the most. LED and fluorescent lights make up the majority of the light bulbs used in the building.

Users may not be aware of specific energy-efficient equipment in their units since there is no mention of such installations. From data collected, it was observed that the building has enough windows that provide sufficient light for the interior part of the building and stairways, even though windows are covered by curtains that hinder the entrance of lighting at the ground floor, forcing the users to use artificial light during the daytime. Users could express high satisfaction with natural lighting in their units, but they are not conscious of their energy consumption habits, such as turning off lights and utilizing natural lighting. Discomfort issues related to ventilation was absent due to the reliance on natural elements. Air conditioners and fans are not used because in this building, the high ceiling nature of the building makes all the rooms in the building naturally ventilated. In this building nothing exists as tracking energy use, management for energy performance, and renewable energy usage in the building that promotes continuity of information to ensure that energy-efficient operating strategies are maintained.

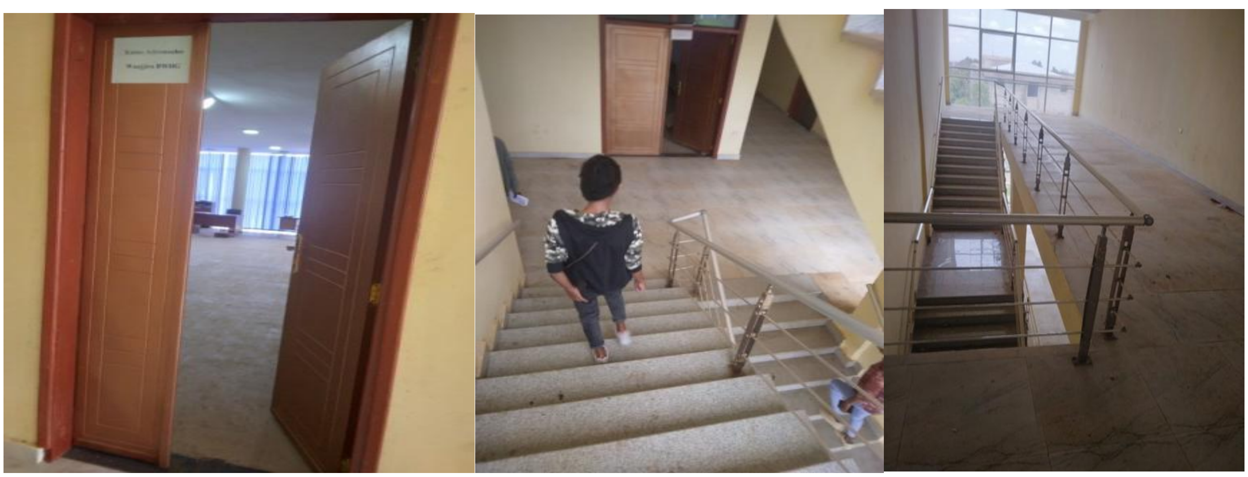

Figure 4.18. Artificial and natural light and ventilation circulation (Source by author; 2023)

4.3.6.4. Indoor Environmental Quality (IEQ)

A. Indoor and Outdoor Space Design for Visual Comfort and Esthetics

From data collected natural ventilation was effective and feeling air circulation is adequate. A source of noise disturbance that affects their comfort was from the busy street outside of the building, because there are not enough trees to buffer such problems.

4.3.7. Building 7: Post Office Building

A. Building's Purpose and Description

The main road that goes from Addis Ababa to Jimma defines this building's location. The ownership title of the building is held by the post office and is located in Woliso town. The building serves a multipurpose function and has an area of 500m^2 and has five floors. It is relatively recent with the age of nine years. This building has only one stair for regular circulation for the tenants or users of the building. There are no fire scape stairs and no a fire extinguisher is installed on every floor. The building has no car parking space. The building serves as a bank, insurance company's offices, automotive training schools, boutiques, optics and dental clinics, private printing presses, game zones, stores, and different government offices are the major services in the building.

Figure 4.19. Post office building source (Source by authors, 2023)

4.3.7.1. Urban Heat Island Effect

Post-office building took almost its entire plot and did not have enough open spaces in the front parts and around the building. The outdoor area had no vegetation or does not have access to green plants around the building areas. The building does not have a green roof. There is reflective coating or cool pavements around the building. The building had no Shading devices (overhangs) that can help to control the amount of sunlight entering the building and prevent excessive heat gain. Additionally, there are no potted plants in all the balconies and around the entrance that minimize the effects of microclimates to create a healthy living environment for tenants, users, and the town.

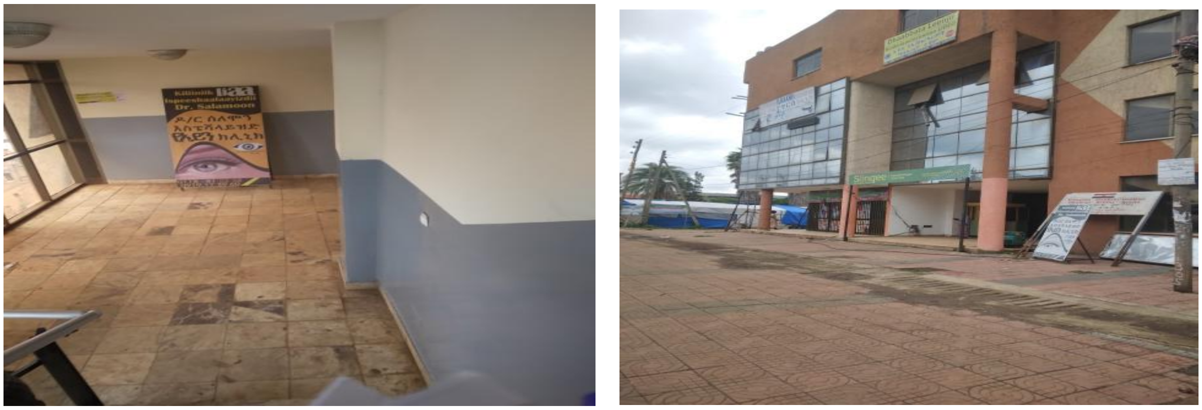

Figure 4.20. Open spaces around post office building (Source by Author, 2023)

4.3.7.2. Water Efficiency

A. Innovative Wastewater Technology and Water Use Reduction

There are currently no notable water-saving devices or practices at the Post Office Building since there is little emphasis on water conservation. No water-efficient fixture metering exists that helps water management and identify opportunities for additional water savings and also, there are no efficient fixtures. During rainy season rainwater from the roof passes through the downpipes to the main drainage line without restoration. Tap water is the main source of water for indoor and outdoor use, such as toilet flushing, cleaning, and others, with two 5,000-liter tankers in case of water loss. Monitoring and managing water consumption at both the individual and building levels are not actively practiced. The building has not implemented any wastewater treatment. Nothing is done to recycle or reuse rainwater and wastewater, potentially leading to inefficiencies in water treatment processes.

4.3.7.3. Energy Efficiency

A. Energy-Efficient Equipment, Natural Lightning, and Ventilation

In the post-office building electricity is the main source of energy for different activities; computers and light bulbs are used the most. Fluorescent lights and bulbs make up the majority of the light used in the building. Users may not be aware of specific energy-efficient equipment in their units since there is no mention of such installations. From data collected, it was observed that the building has windows that provide light for the interior part of the building and stairways, but windows are covered by curtains and advertisement that hinder the entrance of light, forcing the users to use artificial light during the daytime. Artificial light is used in some parts of the building's room during the day. They had no satisfaction with natural lighting in their units and they are not conscious of their energy consumption habits, such as turning off lights and utilizing natural lighting. Air conditioners and fans are not used. There is discomfort issues related to lighting or ventilation. Because in this building, there is no properly designed operable windows allow for natural airflow and ventilation. Building nothing exists as tracking energy use, management for energy performance, and renewable energy usage in the building that promotes continuity of information to ensure that energy-efficient operating strategies are maintained.

Figure 4.21. Natural lightning, and Ventilation: (Source by Author, 2023)

4.3.7.4. Indoor Environmental Quality (IEQ)

A. Indoor and Outdoor Space Design for Visual Comfort and Esthetics

From data collected was not effective and air circulation also is not adequate. The Ambient noise level of post office building is noisy because there are no planted trees around to buffer such problems. Lack of dedicated space for parking, the existence of public service provider offices, and the building's location create a noisy environment for the tenants or users of the building.

4.3.8. Building 8: Refera Building

A. Building's Purpose and Description

The location of this building is defined by the main road that runs from Addis Ababa to Jimma. The building is privately owned and situated in town center. It serves a multifunctional purpose, spanning an area of 400m^2 and encompassing five floors. It is relatively with an age of fifteen years. The building features stairs for regular circulation among tenants or users. Additionally, it includes an underground area utilized as a car parking space. Functionally, the building accommodates various uses such as banks, micro-institute offices, and regulatory offices.

Figure 4.22. External space of Refera Building (Source by author, 2023)

4.3.8.1. Urban Heat Island Effect

Refera building had open spaces in the front parts of the building, and also at the back of the building it has enough open spaces. The building does not have a green roof. There is no reflective coating or cool pavements around the building. Refera building had no Shading devices (overhangs) that can help to control the amount of sunlight entering. There was a backyard parking space. There are no urban heat management strategies, such as cool corridors; no potted plants in all the balconies except small, planted trees around the entrance that minimize the effects of microclimates.

Figure 4.23. Open spaces around post office building (Source by Author, 2023)

4.3.8.2. Water Efficiency

A. Innovative Wastewater Technology and Water Use Reduction

In Refera building, there were no significant water-saving technologies. During rainy season rainwater from the roof passes through the downpipes to the main drainage line without restoration. Municipal water is the main source of water for indoor and outdoor use, such as toilet flushing, cleaning, and others, with three 5,000-liter tankers in case of water loss. Monitoring and managing water consumption at both the individual and building levels are not actively practiced. The building has not implemented any wastewater treatment. Nothing is done to recycle or reuse rainwater and wastewater, potentially leading to inefficiencies in water treatment processes.

4.3.8.3. Energy Efficiency

A. Energy-Efficient Equipment, Natural Lightning, and Ventilation

From data collected, it was observed that the building has enough windows that provide sufficient light for the interior part of the building and stairways, even though some of the windows are covered by curtains and advertising paper that hinder the entrance of light, forcing the users to use artificial light during the daytime. In Refera building electricity is the main source of energy for different activities like water heating, computers and light bulbs are used. Occupants have no control over lighting and ventilation. Artificial light is not used in all parts of the rooms carelessly during the day, except the ground floor and first floor that is due to the window are covered by advertising paper. In Refera building nothing exists as tracking energy use, management for energy performance, and renewable energy usage in the building that promotes continuity of information to ensure that energy-efficient operating strategies are maintained.

Figure 4.24. Artificial lighting and Ventilation (Source by Author, 2023)

4.3.8.4. Indoor Environmental Quality (IEQ)

A. Indoor and Outdoor Space Design for Visual Comfort and Esthetics

From data collected natural ventilation was effective and air circulation was good. The Ambient noise level of building is noisy. Lack of dedicated space for parking, the existence of public service provider offices, and the buildings' location create a noisy environment for the tenants or users of the building.

4.3.9. Building 9: Woliso Hotel Building

A. Building's Purpose and Description

The location of this building is delineated by the main road connecting Addis Ababa to Jimma. Privately owned, it is situated in Woliso town and serves multiple functions, including hotel and guest house accommodations. Spanning an area of 400m2, this modern structure was constructed two years ago and comprises five stories. Stairs are utilized for regular circulation among tenants or users, while an open corridor facilitates horizontal movement. Despite fire extinguishers being installed on every floor. Additionally, a small car parking space is available at the front of the building.

Figure 4.25. Satellite map of the Woliso hotel building (Source from Google map and Source by Author, 2023 respectively)

4.3.9.1. Urban Heat Island Effect

The Woliso hotel building had small open spaces in the front parts of the building. The building does not have a green roof. There was no reflective coating or cool pavements around the building. Building had no Shading devices (overhangs) that can help to control the amount of sunlight entering. This new building has insufficient space for parking, making the surrounding of the building congested and chaotic. There are urban heat management strategies, such as cool corridors and potted plants in all the balconies and planted trees around the entrance that minimize the effects of microclimates.

Figure 4.26. Pavement, surrounding trees, parking, and open space (Source by Author, 2023)

4.3.9.2. Water Efficiency

A. Innovative Wastewater Technology and Water Use Reduction

Water-efficient fixture metering exists that helps water management and identify opportunities for additional water savings. During rainy season rainwater from the roof passes through the downpipes to the main drainage line without restoration. Tap water is the main source of water for indoor and outdoor use, such as toilet flushing, cleaning, and others, with two 5,000-liter tankers in case of water loss. Nothing is done to recycle or reuse rainwater and wastewater, potentially leading to inefficiencies in water treatment processes.

4.3.9.3. Energy Efficiency

A. Energy-Efficient Equipment, Natural Lightning, and Ventilation

From data collected during site observation, it was observed that the building has enough windows that provide sufficient light for the interior part of the building and stairways. Electricity and solar energy are source of energy for different activities like water heating, cooking, light bulbs are used. LED lights make up the majority of the light bulbs used in the building. The high ceiling nature of the building makes all the rooms naturally. Occupants have control over lighting and ventilation.

Figure 4.27. Natural lightning and Ventilation (Source by Author, 2023)

4.3.9.4. Indoor Environmental Quality (IEQ)

A. Indoor and Outdoor Space Design for Visual Comfort and Esthetics

From data collected natural ventilation was effective and feeling air circulation is adequate. The lack of dedicated space for parking and the buildings' location created a noisy environment therefore there are not enough trees acting as a buffer to such problems.

4.3.10. Building 10: Tulu Building

A. Building's Purpose and Description

The building's location is defined by the main road connecting Addis Ababa to Jimma. It is privately owned and situated in the town of Woliso, serving a mixed-use function with a total area of 400m^2. Constructed fourteen years ago, the building comprises five stories. Stairs are utilized for regular circulation among tenants or users of the building. However, there is a lack of fire escape stairs, although fire extinguishers are installed on each floor. The building offers small front parking spaces. It features five floor of a multipurpose building housing various functions including banks, insurance companies, and government offices, printing houses, advertising agencies, sports equipment suppliers' offices, game zones, and consulting offices.

Figure 4.28. Satellite map of the Tulu building (Source from Google map)

4.3.10.1. Urban Heat Island Effect

Tulu building has no space and has no green area surrounding it. In spite of enough trees and plants around the building, there were no potted plants in all the balconies and entrances of buildings that minimize the effects of microclimates to create a healthy living environment for tenants, users, and the town. The building does not have a green roof. Around the building, footprints are covered by gravel. There is no use of shading devices, such as overhangs, louvers, or blinds, which can help control the amount of sunlight entering the building and prevent excessive heat gain. There are no urban heat management strategies, such as cool corridors, green infrastructure, and proper ventilation systems that can help combat excessive heat in densely populated areas.

Figure 4.29. Open spaces around post office building (Source by Author, 2023)

4.3.10.2. Water Efficiency

A. Innovative Wastewater Technology and Water Use Reduction

In Tulu building, there were no any significant water-saving technologies or practices currently implemented in the building, as the focus on water conservation is lacking. No water-efficient fixture metering exists that helps water management and identify opportunities for additional water savings and also, there are no efficient fixtures. Municipal water is the main source of water for all indoor and outdoor water used in the building. During data collection it indicated that buildings do not have water-efficient fixtures with one 5,000-liter tanker in case of water loss. They use toilets and water outside the building. There is no gray water and rainwater harvesting systems. There is no restoration of rainwater and recycling or reuse of wastewater; instead, it passes through the main drainage line. The building had not implemented any wastewater treatment.

4.3.10.3. Energy Efficiency

A. Energy-Efficient Equipment, Natural Lightning, and Ventilation

In Tulu building, electricity is the main source of energy for different activities; computers and light bulbs are used the most. Bulb lights make up most of the light bulbs used in the building. Users may not be aware of specific energy-efficient equipment in their units since there is no mention of such installations. From data collected during site observation, it was observed that the building does not have enough windows that provide sufficient light for the interior part of the building and stairways. Users could not express high satisfaction with natural lighting in their units, therefore Artificial light was used during the day. Air conditioners and fans are not used at all. There is discomfort issues related to lighting or ventilation. Because in this building, there were no properly designed operable windows that allow for natural airflow and ventilation and reduce the dependence on mechanical cooling systems. In this building nothing exists as tracking energy use, management for energy performance, and renewable energy usage in the building that promotes continuity of information to ensure that energy-efficient operating strategies are maintained.

Figure 4.30. Natural lightning, and Ventilation (Source by Author, 2023)

4.3.10.4. Indoor Environmental Quality (IEQ)

A. Indoor And Outdoor Space Design for Visual Comfort and Esthetics

From data collected natural ventilation was not effective and air circulation not adequate. The Ambient noise level of building is noisy. A source of noise disturbance that affects their comfort was from the busy street outside of the building because there are not enough trees to protect against such problems.

4.4. Knowledge, Awareness and Practice of Construction Stakeholders

The data on the knowledge, awareness and practice of construction stakeholders regarding the environmental sustainability concept in building construction was collected from twenty-four (24) participants. In order to assess the level of knowledge, awareness and practice of the theory of green building and sustainability construction, the respondents were asked eight questions for each three topics. The respondents' views on this objective were used to form an opinion on their knowledge, awareness and practice of sustainability and green building construction. The presentation and analysis of the data obtained was done using mean, relative importance index (RII), percentages, and tables. The study employed a systematic measurement approach using a five-point Likert scale to assess the Knowledge, Awareness, and Practice (KAP) levels of 24 construction stakeholders in Woliso town.

Knowledge parameters reveal a strong grasp of environmental regulations related to building construction (RII of 0.542) and the benefits of using sustainable materials (RII of 0.533). These findings are consistent with the "Traditional and Modern Methods of Construction: Comparative Study of the Sustainability of Single-Family Homes," which highlights the advantages of sustainable materials [83]. However, the lower RII value for familiarity with green building certification (0.483) suggests a knowledge gap in this area. This gap could be addressed by providing more information and training on green building certification processes and their benefits, which are essential components of green building standards. (**Table 4.6**).

Table 4.6: Knowledge of construction stakeholders on environmental sustainability of building construction projects at Woliso town

Knowledge	Frequency					RII
	5	4	3	2	1	
1. Awareness of environmental regulations related to building construction	0	6	8	7	3	0.542
2. Knowledge of the benefits of using sustainable materials in construction	0	5	9	7	3	0.533
3. Familiarity with the concept of green building certification	0	4	7	8	5	0.483
4. Understanding of the impact of construction activities on local ecosystems	0	5	8	8	3	0.525
5. Knowledge of energy-efficient building designs	0	4	9	7	4	0.508
6. Awareness of the importance of waste management in construction projects	0	7	8	6	3	0.525
7. Knowledge of water conservation techniques in building construction	0	5	7	8	4	0.508
8. Understanding of the role of renewable energy in sustainable construction	0	4	8	8	4	0.500

Awareness parameters show that stakeholders have a strong understanding of the environmental impact of traditional construction methods (RII of 0.533) and the importance of sustainable construction practices (RII of 0.542). These findings are in line with the "Blueprints for Sustainability: An In-Depth Study of Construction," which underscores the negative effects of conventional practices and the benefits of sustainable alternatives [84]. The recognition of environmental policies implemented by local authorities (RII of 0.500) also supports the role of local regulations in promoting sustainability. However, lower awareness of the benefits of green roofs and walls (RII of 0.492) indicates that newer sustainable construction concepts are less familiar to stakeholders. This gap suggests the need for educational initiatives to raise awareness about the full spectrum of green building techniques.

Table 4.7: Awareness of construction stakeholders on environmental sustainability of building construction projects at Woliso town

Awareness	Frequency					RII
	5	4	3	2	1	
1. Awareness of the environmental impact of traditional construction methods	0	5	9	7	3	0.533
2. Recognition of the importance of sustainable construction practices	0	6	8	7	3	0.542
3. Awareness of the environmental policies implemented by local authorities	0	4	8	8	4	0.500
4. Understanding of the significance of reducing carbon emissions in construction	0	5	7	8	4	0.508
5. Awareness of the benefits of green roofs and walls	0	4	7	9	4	0.492
6. Recognition of the importance of biodiversity conservation in construction projects	0	5	8	7	4	0.517
7. Awareness of the environmental impact of construction waste	0	6	9	6	3	0.542
8. Understanding of the need for sustainable urban planning	0	5	8	8	3	0.525

The analysis of actual practices implemented by stakeholders reveals that adherence to waste management protocols on-site and compliance with environmental regulations (both with RII of 0.542) are the most prioritized practices among stakeholders. This aligns with the findings of the study "Enhancing Environmental Sustainability in Construction: which emphasizes the importance of effective waste management and regulatory compliance in promoting sustainable construction [85]. The relatively high engagement in practices that minimize the environmental impact of construction (RII of 0.533) further supports this alignment, as it reflects a commitment to reducing the environmental footprint, consistent with the principles of green building standards like LEED and BREEAM. However, lower RII values for the use of eco-friendly materials (0.508) and prioritization of renewable energy sources (0.492) suggest that while basic `sustainable practices are being implemented, more advanced techniques that require higher technical expertise or financial investment are less frequently adopted. This highlights the need for increased training and resources to promote advanced sustainable practices. (**Table 4.8**).

Table 4.8: Practice of construction stakeholders on environmental sustainability of building construction projects at Woliso town

Practice	Frequency					RII
	5	4	3	2	1	
1. Implementation of sustainable practices in construction projects	0	5	8	8	3	0.525
2. Use of eco-friendly materials in construction projects	0	4	9	7	4	0.508
3. Adherence to waste management protocols on-site	0	6	8	7	3	0.542
4. Incorporation of energy-efficient designs in projects	0	5	7	8	4	0.508
5. Use of water conservation techniques in construction projects	0	4	8	8	4	0.500
6. Prioritization of renewable energy sources in projects	0	4	7	9	4	0.492
7. Engagement in practices that minimize the environmental impact of construction	0	5	9	7	3	0.533
8. Compliance with environmental regulations in projects	0	6	8	7	3	0.542

Moreover, besides rating the knowledge, awareness and practice of environmental sustainability in construction projects, this key information also provided a response on the area. The description was summarized and also their verbatim was included as follows.

4.4.1. Urban Heat Island Effect

From data gathered, some of the building owners/facility managers were familiar with the concept of urban heat islands and understood their potential impact on the town. There are temperature variations, especially during hotter seasons. Most of the response from the users of the building has the same idea and closeness. Some of the buildings have green spaces; about green roof all of the buildings currently do not have green roofs. And all respondents believe vegetation plays a crucial role in mitigating heat island effects. They see vegetation as essential for providing shade, absorbing heat, and improving overall air quality. Participants from the Cooperative Bank of Woliso, Woliso hotel building and Woliso woreda building replied that:

“This building was designed with considerations for natural ventilation, shading, and reflective materials that minimize heat absorption.”

4.4.2. Water Consumption Pattern

The potential benefits include reduced reliance on municipal water and cost savings. During data collection for the question “Are you aware of your building's total water consumption?” participants from Haro Wonchi building and Woliso hotel building replied that,

“Yes, I am aware of our total water consumption, I monitor it regularly through water meter readings, but the building has not implemented water conservation practices".

But the buildings do not have low-flow faucets, water-efficient appliances, and ongoing awareness campaigns to encourage responsible water use.

4.4.3. Energy Consumption

In the building, there are no automatic lighting controls implemented and there are no occupancy sensors in common areas to ensure lights are only active when needed. From the data collected a mix of LED and compact fluorescent lamps (CFL) lighting systems were used in most of the buildings. From the participants, one of the interviewers answered that:

"Building has a combination of mechanical and natural ventilation systems. The mechanical systems are designed to provide fresh air while minimizing energy consumption."

4.4.4. Indoor Environmental Quality

From the data gathered most of the owners/facility managers raised the problem of indoor environmental quality, especially ventilation and described as:

"Mechanical ventilation system that ensures fresh air circulation and regularly assesses its effectiveness and adjusts as needed. But no regular checks and assessments that help to maintain acceptable indoor air quality done in our settings usually, Users implemented measures such as regular cleaning and using air purifiers to minimize indoor air pollutants."

On the issue of noise level and sound management, the participant explained it as follows:

"Noise levels are not generally manageable, but we understand it's an important aspect. Noise reduction strategies are not implemented in building areas."

4.5. Factors that Affect the Environmental Sustainability of Buildings

Moreover, the owners/facility managers, environmental protection bureau officials and construction stakeholders were asked about factors that affect the environmental sustainability of buildings and contribute to sustainable development. Accordingly, they have listed out the common and rated based on their level of importance in affecting the application of sustainability concept in construction building in the setting.

4.5.1. Lack of awareness

Lack of awareness about the environmental sustainability of buildings was also one of the themes considered as factors affecting its application.

"The concept of green building is new to most the policy and decision makers. Because of this, architects, engineers, and decision-makers have not paid enough attention to effectively integrating the principles of green building into the way that buildings are now constructed. Even if they are concerned about environmental issues, the construction company's goal to incorporate

green building principles into projects is hampered by the stakeholders' lack of awareness." (Key informant interview, 2024).

This comment demonstrates how a lack of awareness and understanding among the key players in the construction sector prevents them from incorporating green building principles into the current construction practices of the country. The absence or limited number of exemplary green building projects in Ethiopia is to blame for the lack of awareness.

4.5.2. Absence of legal and regulatory structures

Respondents revealed that a lack of policies, laws, and regulations poses challenges to mainstreaming the practice of green building in the construction sector of Ethiopia in general and in the study area in particular. Respondents further argued that the benefits of green buildings are not recognized by policymakers and are translated into regulations and building codes. The views reflected by most of the key informant interview participants were similar and can be summarized as follows:

"The usage of ecologically unfavorable building materials in the country is a result of a lack of legislative and regulatory frameworks." (Key informant interview, 2024).

4.5.3. Lack of expertise and previous experience in the field

However, the findings of this research revealed that there is a lack of qualified and well-experienced professionals in the field of green buildings, resulting in difficulties in adopting and properly implementing the concepts and principles of green building in the construction industry of the country in general and the study area in particular. All the key informants concurred that the nation suffers from a shortage of skilled professionals, which is a problem that has to be resolved right away. Regarding this, one of the key informants reported that:

"While I am studying civil engineering, I am not sure what green buildings entail. When I initially heard about green buildings, I assumed they were merely structures with vegetation on their roofs and facades. In the public or private sectors, we do not have enough professionals in green buildings and sustainable construction. (Key informant interview, 2024).

4.5.4. The idea that eco-friendly structures are expensive

It was discovered that a major obstacle to fully adopting and putting into practice the green building concept and principles is the perception that investing in a green building will cost more money. According to the information obtained from the key informants, the notion that green buildings are expensive is another major obstacle to the mainstreaming of green building practices in Ethiopia's construction industry. One respondent captured this sentiment by stating:

"I think a big challenge in promoting green building in Ethiopia is expected to be more expensive." (Key informant interview, 2024).

4.6. The Level of the Problem

The severity of major issues related to the LEED standard criteria was depicted in a spider graph below. This depiction was based on ratings out of five (5), derived from an observational checklist and interviews conducted with stakeholders involved in building construction and the existing situations in the town. The primary issue identified as the lack of innovative wastewater technology underscores the importance of implementing advanced water management systems to enhance sustainability in building construction. This finding suggests a critical need for integrating innovative solutions such as grey water recycling and rainwater harvesting to address water scarcity and reduce environmental impact.

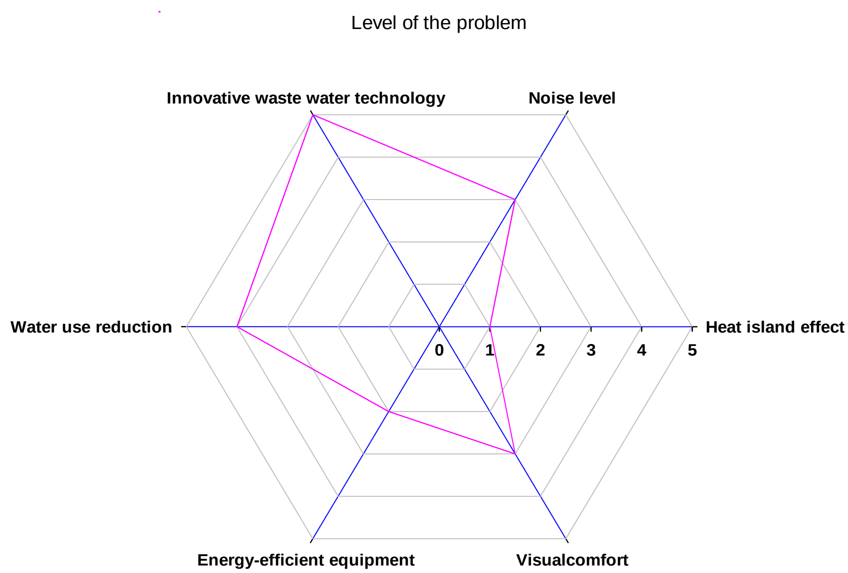

Figure 4.31. The severity of major issues related to the LEED standard criteria.

Innovative Wastewater Technology:

- This category has the highest score, indicating a critical problem area. It suggests the need for advanced water management systems, such as grey water recycling and rainwater harvesting, to reduce environmental impact and address water scarcity.

Noise Level:

- The chart highlights issues with noise pollution, which could affect the quality of life in constructed environments. Solutions may include soundproofing materials and strategic building designs.

Visual Comfort:

- This evaluates how well the building or area accommodates visual harmony, including natural lighting and aesthetic appeal. Enhancements like better window placement or design adjustments could resolve issues.

Energy-Efficient Equipment:

- This factor assesses the utilization of technology that minimizes energy consumption. Implementing solar panels, smart grids, or energy-efficient appliances can significantly enhance sustainability in construction.

Water Use Reduction:

- Challenges in water conservation are highlighted here, emphasizing the need for efficient fixtures, rainwater harvesting systems, and optimized irrigation practices.

The shaded area represents the combined impact across these factors. It emphasizes areas that need urgent attention, like wastewater management technology, while also highlighting the relative performance in other areas. This chart serves as a guide for prioritizing improvements to achieve sustainable and eco-friendly building practices.

In summary, the main issues related to the Urban Heat Island Effect include the absence of green roofs to mitigate solar heat on wide, dark-colored roofs, and insufficient environmentally sensitive site management practices to maintain a clean, safe building exterior while supporting high-performance operations. Regarding water usage, the gaps include complete reliance on municipal tap water for all activities, lack of building-level water metering to track consumption and identify savings opportunities, insufficient knowledge about wastewater treatment technology and design, and no water recycling practices. In the Energy and Atmosphere category, key gaps include the lack of renewable energy utilization, reliance on artificial lighting during the day, obstruction of natural light by partitions, curtains, and advertising materials, and the tendency to leave lights and appliances on when not in use due to negligence and small partitioned spaces. Some buildings also use LED bulbs, which increase energy consumption. Finally, issues related to indoor environmental quality include fluctuating indoor temperatures, lack of indoor air quality performance measures to maintain occupant well-being, and improper room layouts that fail to utilize natural ventilation and lighting effectively.

4.7. Discussion on the Envir0onmental Sustainability Aspects of the Selected Buildings

4.7.1. Urban Heat Island Effect

Based on observations made during the study, it was found that all buildings in Woliso town have open spaces that can be utilized for creating green areas. To gain a better understanding of the situation, respondents were asked if they had any green infrastructure in their office or office area. Accordingly, the current findings showed that 51.5% of respondents reported thermal discomfort due to high temperatures. Moreover, while some measures are in place, there is still a significant portion of respondents (39.2%) who lack adequate greenery and shading solutions, suggesting room for improvement to meet LEED standards. Comparing these findings with the LEED criteria, the Heat Island Reduction credit aims to minimize UHI effects through strategies such as increasing vegetation, using reflective materials, and implementing green roofs [57].

However, it was noted that some of the assessed buildings had greenery that could effectively reduce heat buildings such as the Woliso town administration office, the Woliso hotel building, and the Haro Wonchi building had relatively better green infrastructure in their compounds and the other does not have plantations in their compound. Globally, research has shown similar trends. A comprehensive review of global UHI studies over the past 50 years indicates that urban geometry, material choices, and vegetation cover are critical factors influencing UHI formation[86]. For instance, studies in Southeast Asian cities have emphasized the importance of green spaces and urban shading in mitigating UHI effects [87]. This aligns with the current survey results, where 60.8% of respondents recognized the presence of vegetation or shading devices as beneficial.

Additionally, it was noted that only two sites, namely Haro Wonchi and Woliso hotel building, had individual vegetation in containers at entrances, stairs, and windows within the buildings. All the assessed buildings do not have green roofs. The trend of households creating greenery in containers be encouraged and adopted widely to regain the greenery lost during site clearance for green land development. In comparison to the findings of the present research study on green infrastructure in buildings in Woliso town, other studies have also examined the importance of green spaces and vegetation in urban environments. This was similar to a study conducted by Koricho and Song et al. [88] in a similar urban setting in Ethiopia. It was found that there is a lack of green infrastructure in most buildings, with only a few having green spaces or green roofs. The study also highlighted the importance of encouraging the trend of households creating greenery in containers to regain lost greenery during site clearance for development.

Another study by Escobedo et al. [89]) investigated the benefits of urban green spaces in mitigating heat island effects and enhancing environmental quality. The study emphasized the role of trees, green roofs, and vegetation in reducing heat buildup in urban areas and improving air quality. This aligns with the observation of greenery spaces and green roofs in some of the assessed buildings in Woliso town, which could effectively reduce heat and enhance environmental quality.

Furthermore, a study by Nowak et al. [90] explored the impact of urban vegetation on energy consumption and found that trees and green infrastructure can help reduce energy use for heating and cooling in buildings. The study highlighted the potential of green roofs, trees, and vegetation in providing shade, reducing solar heat gain, and improving thermal comfort, which resonates with the importance of green infrastructure in buildings identified in the present research. Moreover, a study by Manes, Incerti et al. [91] focused on the ecosystem services provided by urban green spaces, including air purification, temperature regulation, and aesthetic value. The study underscored the importance of incorporating green infrastructure into urban planning and design to enhance environmental sustainability and human well-being. This emphasizes the significance of encouraging the trend of creating greenery in containers within buildings, as noted in the present research study. In general, these studies highlight the multiple benefits of green infrastructure in urban environments, including heat reduction, energy savings, air quality improvement, and aesthetic enhancement. Encouraging the integration of green spaces and vegetation in buildings can contribute to creating more sustainable and resilient urban landscapes.

4.7.2. Energy Efficiency

Energy efficiency practices within building units are crucial for sustainability. In construction industries has been a push towards energy-efficient technologies, with a significant proportion of buildings now incorporating energy-saving measures [92]. The present research study considered several criteria related to energy consumption in the assessed buildings. These criteria included the use of renewable energies, the knowledge about renewable energies among the respondents, the use of energy-efficient equipment, and the number of energy-consuming materials used during the day. In the current survey the results didn't reflect this trend, with 31.5% of respondents reporting on the installation of energy-efficient equipment. Other studies have shown that optimizing natural lighting and incorporating renewable energy sources can further enhance energy efficiency [86]. However, your survey indicates that 72.3% of respondents still rely on artificial lighting, and only 20% use renewable energy sources. This suggests a need for greater emphasis on natural lighting solutions and renewable energy adoption.

The LEED criteria for energy efficiency include the use of energy-efficient appliances, optimizing natural lighting, and incorporating renewable energy sources [57]. While your survey shows progress in some areas, there is still a significant opportunity to improve the adoption of renewable energy and enhance natural lighting to fully align with LEED standards.

The primary source of energy in all the assessed buildings was found to be electricity except the Woliso hotel building. The most significant contributors to energy consumption were computers and light bulbs. Air conditioners and fans were not used in most of the buildings due to the prevailing weather conditions of the city. Artificial light was observed to be used during the day in most of the assessed buildings. The respondents attributed this to factors such as wall partitions, curtains, size of the windows and plastering of advertisement paper on windows that hindered the entrance of natural light. Some respondents also reported that the light bulbs installed in their buildings were not energy efficient.

In comparison to the present research study, other studies have also explored energy consumption in buildings and highlighted similar themes related to renewable energies, energy-efficient equipment, and energy-consuming materials. One study conducted by Balaras et al. [93] examined the energy consumption patterns in office buildings and found that electricity was the primary source of energy, similar to the findings in the present study. The study also identified computers and lighting as significant contributors to energy consumption, aligning with the results of the present research. Additionally, Balaras et al[93] emphasized the importance of using energy-efficient lighting solutions to reduce energy consumption, which resonates with the observation of non-energy-efficient light bulbs in some of the assessed buildings in the present study. Furthermore, a study by Sartori et al [94]) investigated the impact of building design on energy consumption and highlighted the importance of natural lighting in reducing the need for artificial lighting. The study emphasized the role of factors such as window size, orientation, and shading devices in optimizing natural light penetration, which is consistent with the findings of the present research regarding the hindrances to natural light entry in some buildings.

Based on the responses provided by the participants, it was found that the light fixtures utilized in the buildings were compared with regards to energy consumption. It was noted that not all light fixtures within the buildings were LED and fluorescent, which are comparatively the least energy-consuming equipment and have the capacity to save energy. In fact, most of the assessed buildings used only incandescent lights on all floors, while some buildings utilized both LEDs and fluorescent lights. None of the buildings were found to utilize alternative or renewable sources of energy, except the Woliso hotel building and the Woliso woreda building which highlights the importance of renewable energy sources in reducing energy usage.

The main function of ventilation is to introduce outdoor air into a building and remove indoor air pollutants. Ventilation can be either natural or mechanical, such as HVAC or AC. According to Chan et al. [95], ventilation is the primary contributor to indoor air quality. Green buildings typically have superior ventilation systems compared to regular buildings, and they can provide a healthier indoor environment for their occupants. During the assessment, it was observed that most of the buildings had good ventilation, with the exception of four buildings (namely, the post office building, Teka building, Refera building, Southwest Shewa zone administration building and Tulu building), which had poor air quality.

Similarly, a study by Cabeza et al. [5] focused on energy-efficient technologies in buildings and emphasized the use of renewable energies and energy-efficient equipment to minimize energy consumption. The study highlighted the potential of solar panels, heat pumps, and other renewable energy sources in reducing reliance on conventional electricity sources, which aligns with the emphasis on renewable energies in the present research study.

4.7.3. Water Efficiency

Water efficiency is another critical area where the current survey results highlight significant gaps. Nationally, the adoption of water-efficient appliances and fixtures is encouraged to reduce potable water consumption. However, only 20% of your respondents reported using such appliances, indicating a need for broader implementation. International studies also emphasize the importance of water conservation. For example, research in arid regions has shown that rainwater harvesting and graywater reuse can significantly reduce dependence on potable water [87]. This is particularly relevant given that 61.5% of our respondents rely on tap water for both indoor and outdoor activities.

The LEED Water Efficiency (WE) Credits focus on reducing water use through high-efficiency fixtures, alternative water sources, and smart monitoring systems [57]. The current survey among tenants suggests that while there is some awareness of water recycling (100% acknowledgment), actual implementation is lacking. Additionally, only 20% of respondents have water metering systems, which are essential for optimizing water use and meeting LEED criteria. According to the observations made using the checklist, it was found that tap water serves as the primary source of water for indoor and outdoor activities in all of the assessed buildings. The buildings have a water metering system in place to monitor their water usage and promote water conservation. But there was a lack of monitoring which means that building users are unable to determine their daily water consumption, which can lead to unnecessary waste. It is worth noting that all of the assessed buildings have a water tanker with varying capacities to mitigate water loss. Participant described how the buildings depend on municipal water provision.

Furthermore, it is found that none of the evaluated buildings have implemented any technical means to recycle or reuse collected rainwater. Of the ten of the selected buildings seven of them didn’t have a functional pipeline. None of the buildings had a water recycling system in place, as well as collect water for later use.

The findings of the present research study on water management in buildings in Woliso town align with and complement the results of other studies that have examined water conservation and management practices in urban settings. A study by Madias et al. [96] reviewed water management practices in residential buildings and highlighted the importance of implementing water metering systems to monitor and promote water conservation. The review emphasized the need for building users to be aware of their daily water consumption to prevent unnecessary waste, which resonates with the observations made in the assessed buildings in Woliso town.

Furthermore, a study by DeOreo et al. [97] explored the benefits of rainwater harvesting and reuse in commercial buildings and residential complexes. The study emphasized the potential of collecting and using rainwater for indoor and outdoor activities to reduce reliance on municipal water supply and promote sustainable water management practices. This aligns with the participant's description of the lack of rainwater collection systems in the assessed buildings in Woliso town.

Moreover, a study by Alireza et al [98] focused on the implementation of water recycling systems in buildings to reduce water consumption and promote water reuse. The study highlighted the importance of incorporating technical means for recycling and reusing water to enhance water efficiency and sustainability. This contrasts with the findings of the present research study, which revealed that none of the evaluated buildings had implemented water recycling systems or collected rainwater for later use. Overall, these studies underscore the importance of implementing water metering systems, promoting rainwater harvesting and reuse, and incorporating water recycling systems in buildings to enhance water conservation and sustainability. Encouraging building users to monitor their water usage, implement rainwater collection systems, and recycle water can contribute to more efficient and environmentally friendly water management practices.

4.7.4. Indoor Environmental Quality

Lighting has a significant impact on indoor environment quality [99].. It affects occupants in both physical and psychological ways. The current study results show that 73.1% of respondents have experienced discomfort due to lighting or ventilation issues, and 86.2% reported discomfort related to thermal comfort.

A well-functioning window is one that allows enough light so that occupants do not have to turn on artificial light in the daytime. If the rooms are well lightened and ventilated, the users of those rooms will have excellent performance and efficiency. Rooms with windows are a comfortable work environment and easily adoptable to live in. Out of a total of 10 buildings, 3 buildings had all rooms naturally lit. In the other 3 buildings, most of their rooms were well lit. The remaining buildings had some rooms with natural lighting. Furthermore, several issues were observed during the survey of selected buildings. These include small windows that do not allow sufficient light to enter, and windows facing southwest without proper shading, which permits harsh sunlight to enter and makes the room unbearable to stay in. Additionally, some windows allow too much light and wind, preventing occupants from comfortably performing their tasks.

The findings of the present research study on the impact of lighting on indoor environment quality in buildings in Woliso town are in line with the results of a study conducted in Addis Ababa [36] regarding the importance of lighting for occupant comfort, safety, and productivity. Both studies emphasize the significance of natural light in indoor spaces and its effects on occupants in physical and psychological ways. They highlight how well-functioning windows that allow sufficient natural light can enhance occupants' performance and efficiency. In terms of specific issues related to lighting and windows, both studies identified common problems such as small windows that do not let in enough light, windows facing southwest without proper shading causing discomfort, and windows letting too much light and wind in hindering occupants from performing effectively. The impact of insufficient natural light due to factors like partitions, advertisements, and improper window design was also noted as a shared concern affecting occupants' well-being and energy usage.

Furthermore, both studies observed that a significant number of buildings surveyed had issues with indoor environment quality, energy usage, functional layout, and waste management systems compared to green buildings. This highlights the need for improvements in building design, lighting, and ventilation systems to create healthier and more sustainable indoor environments.

The study conducted in Woliso town reveals that construction stakeholders have a moderate to good level of knowledge and awareness regarding environmental sustainability, with particular strengths in waste management and environmental regulations. However, there are notable gaps in understanding green building certification and advanced sustainable practices. This aligns with findings from other studies, such as Deshvena (2024), which emphasize the importance of waste management and energy-efficient designs in reducing the environmental footprint [100]. Similarly, Ntakana and Ahmi (2024) highlight the need for material innovation and environmental impact assessment, which resonates with the focus on sustainable materials and ecosystem impacts in the current study [101].

In terms of practical implementation, your study indicates that basic environmental practices are being adopted, but more advanced techniques like water conservation and renewable energy usage are less frequently implemented. This is consistent with Deshvena et al [100] findings that advanced waste management and energy-efficient designs can significantly reduce environmental impact. The gap between knowledge and practice is also noted in Ntakana and Ahmi's study [101]., which suggests that supportive policies and exposure to successful projects are crucial for advancing sustainable construction.

Several barriers to sustainable construction were identified, including limited knowledge, lack of regulatory frameworks, insufficient expertise, and perceptions of high costs. These challenges are echoed in other studies, which call for increased investment in sustainable technologies, robust policies, and targeted training programs [100, 102]. Addressing these gaps is essential for enhancing sustainable construction practices in Woliso town and similar contexts.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Regarding the existing nature of buildings in relation to green building standards, the study found significant gaps in Woliso town. The assessed buildings generally fell short in areas such as urban heat island mitigation, water efficiency, energy performance, and indoor environmental quality. Many buildings lacked proper shading, green roofs, and cool pavements to reduce heat island effects. Water-saving fixtures and rainwater harvesting systems were largely absent. Energy efficiency measures like proper insulation, natural lighting, and renewable energy sources were minimal. Indoor air quality and thermal comfort also needed improvement in most buildings.

The assessment of knowledge and practice among construction stakeholders revealed a mixed picture. While there was some basic awareness of environmental sustainability concepts, this knowledge was not consistently translated into practice. Many stakeholders showed interest in sustainable building practices but lacked comprehensive understanding or practical experience in implementing them. There were gaps in awareness about specific green building strategies and their benefits. The study also indicated a need for more education and training programs to enhance stakeholders' knowledge and skills in sustainable construction.

Several factors were identified as affecting environmental sustainability in building construction in Woliso town. These included a lack of comprehensive understanding of sustainability concepts, absence of strong regulatory frameworks mandating green building practices, limited expertise and experience in sustainable construction methods, and perceptions about the high costs of environmentally friendly building techniques.

5.2. Recommendations

UHI:

- Increase vegetation coverage around buildings by planting trees and green roofs.
- Use reflective or cool roofing materials and permeable pavements to reduce heat absorption.
- Design buildings with proper shading devices to minimize direct heat exposure.

Water Efficiency:

- Increase Water-Efficient Fixtures & Appliances (WE Credit 2 – Water Use Reduction)
- Implement graywater recycling for toilet flushing.
- Deploy water metering systems to track real-time water consumption and detect leaks.

Energy Efficiency:

- Implement energy-efficient appliances and lighting (LED technology).
- Encourage the use of passive design strategies, such as natural ventilation and daylighting, to reduce reliance on artificial cooling and lighting.
- Promote renewable energy integration, including solar panels, for sustainable power supply

Indoor Environmental Quality:

- Ensure proper ventilation systems and use of non-toxic building materials to enhance indoor air quality.
- Improve natural lighting access to minimize artificial lighting use and enhance occupant well-being.
- Implement noise control measures, such as insulation and green barriers, to reduce external disturbances.

Based on the findings the following were the specific recommendations for relevant stakeholders to improve the environmental sustainability of building construction projects in Woliso town:

5.2.1. For construction offices and regulatory bodies:

- Develop and implement comprehensive green building codes and standards tailored to the local context.
- Introduce incentives (e.g., tax breaks, expedited permitting) for developers who incorporate sustainable features in their projects.
- Conduct regular training programs for construction professionals on sustainable building practices.
- Establish a local green building certification system or adopt an existing one like LEED.

- Enforce stricter environmental impact assessments for new construction projects.

5.2.2. For architects and designers:

- Prioritize passive design strategies to reduce energy consumption (e.g., building orientation, natural ventilation).
- Incorporate green spaces and cool pavements in building designs to mitigate urban heat island effects.
- Specify water-efficient fixtures and consider rainwater harvesting systems in all designs.
- Use sustainable and locally sourced materials where possible.
- Design for improved indoor air quality and thermal comfort.

5.2.3. For contractors and construction experts:

- Invest in training programs for workers on sustainable construction techniques.
- Implement waste reduction and recycling programs on construction sites.
- Adopt energy-efficient construction methods and equipment.
- Ensure proper implementation of sustainable design features during construction.
- Develop expertise in installing and maintaining green building technologies.

5.2.4. For building owners and operators:

- Prioritize regular maintenance of building systems to ensure optimal energy and water efficiency.
- Implement energy and water consumption monitoring systems.
- Educate building occupants on sustainable practices and energy-saving behaviors.
- Consider retrofitting existing buildings with green technologies.
- Prioritize the use of environmentally friendly cleaning products and maintenance practices.

5.2.5. For educational institutions:

- Integrate sustainable construction practices into curriculum for architecture, engineering, and construction management programs.
- Collaborate with industry partners to provide practical experience in sustainable building projects.
- Conduct research on locally appropriate green building technologies and practices.

5.2.6. For environmental protection agencies:

- Develop guidelines for assessing and mitigating the environmental impact of construction projects.

- Conduct regular audits of buildings for compliance with environmental standards.
- Collaborate with other stakeholders to promote awareness about environmental sustainability in construction.

By implementing these recommendations, stakeholders can contribute to improving the environmental sustainability of building construction projects in Woliso town, potentially leading to more resource-efficient, healthier, and environmentally friendly buildings.

REFERENCES

1. Ding, G.K., *Sustainable construction—The role of environmental assessment tools.* Journal of environmental management, 2008. **86**(3): p. 451-464.
2. Ortiz, O., F. Castells, and G. Sonnemann, *Sustainability in the construction industry: A review of recent developments based on LCA.* Construction and building materials, 2009. **23**(1): p. 28-39.
3. Sev, A., *How can the construction industry contribute to sustainable development? A conceptual framework.* Sustainable Development, 2009. **17**(3): p. 161-173.
4. Akadiri, P.O., E.A. Chinyio, and P.O. Olomolaiye, *Design of a sustainable building: A conceptual framework for implementing sustainability in the building sector.* Buildings, 2012. **2**(2): p. 126-152.
5. Cabeza, L.F., et al., *Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review.* Renewable and sustainable energy reviews, 2014. **29**: p. 394-416.
6. Kamar, K.A.M., et al., *Collaboration initiative on green construction and sustainability through Industrialized Buildings Systems (IBS) in the Malaysian construction industry.* International Journal of Sustainable Construction Engineering and Technology, 2010. **1**(1): p. 119-127.
7. Aghdam, K.A., et al., *Approaching green buildings using eco-efficient construction materials: A review of the state-of-the-art.* Journal of Construction Engineering and Project Management, 2018. **8**(3): p. 1-23.
8. Kedir, F. and D.M. Hall, *Resource efficiency in industrialized housing construction–A systematic review of current performance and future opportunities.* Journal of Cleaner Production, 2021. **286**: p. 125443.
9. Shan, M., B.-G. Hwang, and L. Zhu, *A global review of sustainable construction project financing: policies, practices, and research efforts.* Sustainability, 2017. **9**(12): p. 2347.
10. Kibert, C.J., *Sustainable Construction at the Start of the 21st Century.* Int. E-Journal Constr, 2003. **2003**: p. 1-7.
11. Oláh, J., et al., *Impact of Industry 4.0 on environmental sustainability.* Sustainability, 2020. **12**(11): p. 4674.
12. Industry, B.T., *Sustainable building and construction: facts and figures.* Ind Environ, 2003. **26**(2-3): p. 5-8.
13. Yudelson, J., *Green building A to Z: Understanding the language of green building*. 2007: New Society Publishers.
14. Verma, A.K., *Sustainable development and environmental ethics.* International Journal on Environmental Sciences, 2019. **10**(1): p. 1-5.
15. Newman, P. and J. Kenworthy, *Sustainability and cities: overcoming automobile dependence*. 1999: Island press.
16. DE JANEIRO, F.S.T.R., *Annex 1. Johannesburg Declaration on Sustainable Development.* International Environmental Agreements: Politics, Law and Economics, 2002. **2**: p. 403-406.
17. Millennium ecosystem assessment, M., *Ecosystems and human well-being*. Vol. 5. 2005: Island press Washington, DC.
18. Kleerekoper, L., M. Van Esch, and T.B. Salcedo, *How to make a city climate-proof, addressing the urban heat island effect.* Resources, Conservation and Recycling, 2012. **64**: p. 30-38.
19. Aggarwal, R.M., et al., *How do variations in Urban Heat Islands in space and time influence household water use? The case of Phoenix, Arizona.* Water Resources Research, 2012. **48**(6).
20. Taha, H., et al., *Residential cooling loads and the urban heat island—the effects of albedo.* Building and environment, 1988. **23**(4): p. 271-283.
21. Kibert, C.J., *Sustainable construction: green building design and delivery*. 2016: John Wiley & Sons.

22. Tam, V.W., et al., *A review on international ecological legislation on energy consumption: greenhouse gas emission management.* International Journal of Construction Management, 2021. **21**(6): p. 631-647.
23. Darko, A., et al., *Influences of barriers, drivers, and promotion strategies on green building technologies adoption in developing countries: The Ghanaian case.* Journal of Cleaner Production, 2018. **200**: p. 687-703.
24. Samari, M., et al., *The investigation of the barriers in developing green building in Malaysia.* Modern applied science, 2013. **7**(2): p. 1.
25. (FDRE), F.D.R.o.E., *Ethiopia's Constitution of 1994; https://www.constituteproject.org/constitution/Ethiopia_1994.pdf access date 23 Jan 2023*. 1994.
26. Anshebo, M.A., W.J. Mengesha, and D.L. Sokido, *Developing a Green Building Assessment Tool for Ethiopia.* Heliyon, 2022. **8**(9): p. e10569.
27. Omer, A.M., *Energy, environment and sustainable development.* Renewable and sustainable energy reviews, 2008. **12**(9): p. 2265-2300.
28. Bani Masoud, A., *Post Modernism and architecture.* Khak publication, Iran, 2007.
29. Zabihi, H. and F. Habib, *Sustainability in building and construction: revising definitions and concepts.* International Journal of Emerging Sciences, 2012. **2**(4): p. 570.
30. Neyestani, B., *A review on sustainable building (green building).* Available at SSRN 2968885, 2017.
31. WBC, *The World Green Building Council (WorldGBC) ; ANNUAL REPORT 2021; avaialble online https://worldgbc.org/wp-content/uploads/2022/08/WorldGBC-2021-Annual-Report.pdf; access date 12 Febraury 2024.* 2021.
32. Change, I.C., *The physical science basis.* (No Title), 2013.
33. Bourdeau, L., et al., *Sustainable Development and the Future of Construction. A comparison of visions from various countries.* 1998.
34. Tsoulou, I., et al., *Residential indoor air quality interventions through a social-ecological systems lens: A systematic review.* Indoor air, 2021. **31**(4): p. 958-976.
35. Snavely, J.W., *The US green building council: Designer of the green building Industry.* Graduate School of International Relations and Pacific Studies, University of California, San Diego, 2007.
36. Haileleul, T., *Evaluation of Selected Addis Ababa Buildings with respect to the Green Building Features*. 2015, M. Sc. Thesis in Environmental Planning and Landscape Design.
37. Taffese, W.Z. and K.A. Abegaz, *Embodied energy and CO2 emissions of widely used building materials: The Ethiopian context.* Buildings, 2019. **9**(6): p. 136.
38. Ding, Z., et al., *Green building evaluation system implementation.* Building and Environment, 2018. **133**: p. 32-40.
39. Chau, C.K., M. Tse, and K. Chung, *A choice experiment to estimate the effect of green experience on preferences and willingness-to-pay for green building attributes.* Building and Environment, 2010. **45**(11): p. 2553-2561.
40. Hui, S.C., *Sustainable architecture and building design.* Pokfulam, University of Hongkong, 2013.
41. Omer, A.M., *Renewable building energy systems and passive human comfort solutions.* Renewable and sustainable energy reviews, 2008. **12**(6): p. 1562-1587.
42. Tam, V.W., J.L. Hao, and S. Zeng, *What affects implementation of green buildings? An empirical study in Hong Kong.* International Journal of Strategic Property Management, 2012. **16**(2): p. 115-125.
43. Devanathan, P. and K. Devanathan, *Heat island effects.* Green Building with Concrete: Sustainable Design Construction, 2011: p. 175-226.
44. Castleton, H.F., et al., *Green roofs; building energy savings and the potential for retrofit.* Energy and buildings, 2010. **42**(10): p. 1582-1591.

45. Varma, V.G., *Water-efficient technologies for sustainable development*, in *Current Directions in Water Scarcity Research*. 2022, Elsevier. p. 101-128.
46. Freewan, A.A., *Impact of external shading devices on thermal and daylighting performance of offices in hot climate regions.* Solar Energy, 2014. **102**: p. 14-30.
47. Elliott, H., C. Eon, and J.K. Breadsell, *Improving City vitality through urban heat reduction with green infrastructure and design solutions: A systematic literature review.* Buildings, 2020. **10**(12): p. 219.
48. Che, W.W., et al., *Energy consumption, indoor thermal comfort and air quality in a commercial office with retrofitted heat, ventilation and air conditioning (HVAC) system.* Energy and Buildings, 2019. **201**: p. 202-215.
49. Khan, N. and N. Abas, *Comparative study of energy saving light sources.* Renewable and sustainable energy reviews, 2011. **15**(1): p. 296-309.
50. Hee, W., et al., *The role of window glazing on daylighting and energy saving in buildings.* Renewable and Sustainable Energy Reviews, 2015. **42**: p. 323-343.
51. Kammen, D.M. and D.A. Sunter, *City-integrated renewable energy for urban sustainability.* Science, 2016. **352**(6288): p. 922-928.
52. Kellert, S.R., *Building for life: Designing and understanding the human-nature connection*. 2012: Island press.
53. Nazari-Heris, M., *Natural Energy, Lighting, and Ventilation in Sustainable Buildings*. 2023: Springer Nature.
54. FDRE, *Environmental Impact Assessment Proclamation No. 299/2002.; Avaialble at https://www.fsc.gov.et/Digital-Law-Library/Federal-Laws/ArtMID/1179/ArticleID/632/Environmental-Impact-Assessment-Proclamation-No-2992002%E1%8B%A8%E1%8A%A0%E1%8A%AB%E1%89%A3%E1%89%A2-%E1%89%B0%E1%8D%85%E1%8B%95%E1%8A%96-%E1%8C%8D%E1%88%9D%E1%8C%88%E1%88%9B-%E1%8A%A0%E1%8B%8B%E1%8C%85-%E1%89%81%E1%8C%A5%E1%88%AD-2991995; access 12 october 2023.* 2002.
55. Bragança, L., R. Mateus, and H. Koukkari, *Building sustainability assessment.* Sustainability, 2010. **2**(7): p. 2010-2023.
56. Council, U.G.B., *Green Building Rating System For Existing Buildings. Upgrades, Operations and Maintenance*. 2004, Version.
57. LEED, *LEED certification for existing buildings and spaces;available at https://www.usgbc.org/leed/rating-systems/existing-buildings; access date 20 June 2024.* 2009.
58. Bernardi, E., et al., *An analysis of the most adopted rating systems for assessing the environmental impact of buildings.* Sustainability, 2017. **9**(7): p. 1226.
59. Brem, A., et al., *How do companies certified to ISO 50001 and ISO 14001 perform in LEED and BREEAM assessments?* Energy efficiency, 2020. **13**: p. 751-766.
60. Amiri, A., J. Ottelin, and J. Sorvari, *Are LEED-certified buildings energy-efficient in practice?* Sustainability, 2019. **11**(6): p. 1672.
61. LEED, *LEED 2009 for Existing Buildings: Operations & Maintenance; page 10-110.* 2009.
62. Phelan, P.E., et al., *Urban heat island: mechanisms, implications, and possible remedies.* Annual Review of Environment and Resources, 2015. **40**(1): p. 285-307.
63. Deilami, K., M. Kamruzzaman, and Y. Liu, *Urban heat island effect: A systematic review of spatio-temporal factors, data, methods, and mitigation measures.* International journal of applied earth observation and geoinformation, 2018. **67**: p. 30-42.
64. Yang, J., Z.-H. Wang, and K.E. Kaloush, *Environmental impacts of reflective materials: Is high albedo a 'silver bullet'for mitigating urban heat island?* Renewable and Sustainable Energy Reviews, 2015. **47**: p. 830-843.

65. Thebuwena, A.C.H.J., S.S.M. Samarakoon, and R.C. Ratnayake, *On the Necessity for Improving Water Efficiency in Commercial Buildings: A Green Design Approach in Hot Humid Climates.* Water, 2024. **16**(17): p. 2396.
66. Bensalah, N., *Challenges and Opportunities in Energy Economics: Balancing Cost, Sustainability, and Innovation in the Global Energy Transition.* Modern Economy, 2024. **15**(11): p. 1147-1180.
67. Wood, R.A., *Improving the indoor environment for health, well-being and productivity.* Greening Cities: a new urban ecology, 2003. **30**.
68. Arif, M., et al., *Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature.* International Journal of Sustainable Built Environment, 2016. **5**(1): p. 1-11.
69. Deng, Z., et al., *Impact of Indoor Air Quality and Multi-domain Factors on Human Productivity and Physiological Responses: A Comprehensive Review.* Indoor Air, 2024. **2024**(1): p. 5584960.
70. Chowdhury, S., et al., *Guidelines for robust adaptation to environmental regulations in infrastructure projects.* Journal of Construction Engineering and Management, 2020. **146**(10): p. 04020121.
71. Adebayo, A.A., *Sustainable construction in Africa.* Agenda, 2002. **21**: p. 1-11.
72. Wen, S. and G. Qiang, *Managing stakeholder concerns in green building projects with a view towards achieving social sustainability: A Bayesian-network model.* Frontiers in Environmental Science, 2022. **10**: p. 874367.
73. Gupte, S. and T. Deshmukh, *Green Buildings: Importance to the Key Stakeholders.*
74. Ebeh, C., et al., *Life cycle assessment (LCA) in construction: Methods, applications, and outcomes.* International Journal of Engineering Research and Development, 2024. **20**(8): p. 350-358.
75. Osorio-Gómez, C.C., et al., *Interaction of Life Cycle Assessment (LCA) and BIM in a Construction Project to Reduce the Environmental Footprint.* Civil Engineering Journal, 2025. **11**(1): p. 120-130.
76. Sanhudo, L., et al., *Building information modeling for energy retrofitting–A review.* Renewable and Sustainable Energy Reviews, 2018. **89**: p. 249-260.
77. Alam, M., et al., *Government championed strategies to overcome the barriers to public building energy efficiency retrofit projects.* Sustainable Cities and Society, 2019. **44**: p. 56-69.
78. Aregawi, T. and P.V. Genovese, *Residential land supply for affordable housing in Ethiopia: the political-economic challenges—evidence from three cities in Tigray province.* Journal of Housing and the Built Environment, 2024: p. 1-30.
79. GERESU, B., *ASSESMENT OF REAL-ESTATE PERFORMANCE IN ADDIS ABABA*. 2023, SMU.
80. Zhang, Y.F., et al., *Unlocking Ethiopia's Urban Land and Housing Markets: Synthesis Report.* 2019.
81. Gelan, E., *Green building concepts and technologies in Ethiopia: the case of Wegagen bank headquarters building.* Technologies, 2022. **11**(1): p. 2.
82. Anshebo, M.A., W.J. Mengesha, and D.L. Sokido, *Developing a green building assessment tool for Ethiopia.* Heliyon, 2022. **8**(9).
83. Josa, I. and A. De la Fuente, *Traditional and modern methods of construction: Comparative study of the sustainability of single-family homes.* Structural Concrete, 2024.
84. Ahmi, K.N.a.A., *Blueprints for Sustainability: An In-Depth Study of Construction*

;DOI: 10.5772/intechopen.1005619. Published: 23 October 2024.
85. Deshvena*, Y.N., *Enhancing Environmental Sustainability in Construction:*

Best Practices and Innovative Strategies: available at

https://journalspub/journal/ijcep

2024.

86. Srivastava, V.T., A. Sharma, and S. Jadon, *A review of the formation, mitigation strategies from 50 years of global urban heat island studies.* Environment, Development and Sustainability, 2024: p. 1-18.
87. Nguyen, C.T., et al., *Urban thermal environment under urban expansion and climate change: a regional perspective from Southeast Asian big cities*, in *Climate Change and Cooling Cities*. 2023, Springer. p. 151-167.
88. Koricho, H.H. and S. Song, *Assessment of Urban Greenery Status in Major Cities of Oromia, Ethiopia.* Research in Ecology, 2021. **3**(3): p. 21-27.
89. Escobedo, F.J., T. Kroeger, and J.E. Wagner, *Urban forests and pollution mitigation: Analyzing ecosystem services and disservices.* Environmental pollution, 2011. **159**(8-9): p. 2078-2087.
90. Nowak, D.J., et al., *Tree and forest effects on air quality and human health in the United States.* Environmental pollution, 2014. **193**: p. 119-129.
91. Manes, F., et al., *Urban ecosystem services: tree diversity and stability of tropospheric ozone removal.* Ecological applications, 2012. **22**(1): p. 349-360.
92. EPA, *Heat Island Effect; available at https://www.epa.gov/heatislands; access date 20 December 2024.* 2024.
93. Santamouris, M., et al., *Energy consumption and the potential for energy conservation in school buildings in Hellas.* Energy, 1994. **19**(6): p. 653-660.
94. Sartori, I. and A.G. Hestnes, *Energy use in the life cycle of conventional and low-energy buildings: A review article.* Energy and buildings, 2007. **39**(3): p. 249-257.
95. Chan, W.R., et al., *Ventilation and indoor air quality in new california homes with gas appliances and mechanical ventilation*. 2019, Lawrence Berkeley National Lab.(LBNL), Berkeley, CA (United States).
96. Madias, K. and A. Szymkowiak, *Residential sustainable water usage and water management: Systematic review and future research.* Water, 2022. **14**(7): p. 1027.
97. DeOreo, W.B., et al., *Residential end uses of water, version 2*. 2016: Water Research Foundation.
98. Zakariazadeh, A., et al., *Renewable energy integration in sustainable water systems: A review.* Cleaner Engineering and Technology, 2024: p. 100722.
99. Konstantzos, I., et al., *The effect of lighting environment on task performance in buildings–A review.* Energy and Buildings, 2020. **226**: p. 110394.
100. Deshvena, Y.N., *Enhancing Environmental Sustainability in Construction:Best Practices and Innovative Strategies* International Journal of Construction Engineering and Planning, 2024. **10**(2): p. 21-25.
101. Ntakana, K. and A. Ahmi, *Blueprints for Sustainability: An In-Depth Study of Construction.* Globalization and Sustainability-Ecological, Social and Cultural Perspectives: Ecological, Social and Cultural Perspectives, 2024: p. 339.
102. Moshood, T.D., J.O. Rotimi, and W. Shahzad, *Enhancing sustainability considerations in construction industry projects.* Environment, Development and Sustainability, 2024: p. 1-27.

Appendix A

Questionnaires for Users in the Buildings

This questionnaire was created by a master's Programme student from Jimma University Institute of Technology's construction engineering and management program. Its goal is to gather information on the use of leadership in energy and environmental design (LEED) in green building concepts in the case of an existing building in the southwest Shewa zone of Woliso town. The information provided is intended for academic purposes and should be treated with strict confidentiality.

To participate in this, I would like to request your consent

If you are willing to participate, please I request you to sign here____________Date__________

All help is much appreciated. Thank you!

1. Does your unit have access to windows or openings that can be used for natural ventilation? Yes ☐ No ☐ Not Sure☐
2. Have you experienced any discomfort due to high temperatures inside or outside the building (e.g., heat, humidity) compared to nearby areas, such as streets or open spaces? Yes ☐ No ☐ Not Sure☐
3. Do you notice any differences in temperature between areas inside your unit (e.g., some rooms are hotter than others)? Yes ☐ No ☐ Not Sure☐
4. Are there any measures to mitigate heat vegetation (e.g., green roofs, trees, or shrubs) other shading devices around your building? Yes ☐ No ☐ Not Sure☐
5. Does your building have reflective or cool roofing materials that reduce heat absorption from the sun? Yes ☐ No ☐ Not Sure☐
6. Are there external shading elements (trees, awnings, or similar structures) near your building that help reduce heat from the sun? Yes ☐ No ☐ Not Sure☐
7. Do you use water-efficient appliances in your unit and building? Yes ☐No☐ Not Sure☐
8. Do you use tap water for indoor and outdoor water consumptions activity? Yes ☐ No ☐ Not Sure☐

9. Do you collect and use rainwater? Yes ☐ No ☐ Not Sure☐
10. Do you recycle water? Yes ☐ No ☐ Not Sure☐
11. Do you use Dual flush or low flow toilet? Yes ☐ No ☐ Not Sure☐
12. Are you aware of the energy-efficient equipment installed in your unit (e.g., appliances, lighting)? Yes ☐ No ☐ Not Sure☐
13. Do you use artificial lighting in your daily activities? Yes ☐ No ☐ Not Sure☐
14. Are there specific areas in your unit where you think energy is efficient? Yes ☐ No ☐ Not Sure☐
15. Are there any discomfort issues related to lighting or ventilation that you have experienced? Yes ☐ No ☐ Not Sure☐
16. Do you use a mechanical system to cool your house during hot seasons? Yes ☐ No ☐ Not Sure☐
17. Are there areas that lack sufficient natural light? Yes ☐ No ☐ Not Sure☐
18. Do you use renewable energy? Yes ☐ No ☐ Not Sure☐
19. Do you use energy efficient lamps? Yes ☐ No ☐ Not Sure☐
20. Is there any other source of energy used in your building? Yes ☐ No ☐ Not Sure☐
21. Do you think there is enough air and ventilation in your house? Yes ☐ No ☐ Not Sure☐

Appendix B

Questions assessing the knowledge, awareness, practice of environmental sustainability of building construction projects by construction stakeholders

Dear Participants,

Thank you for taking the time to participate in this survey on the environmental sustainability of building construction projects in Woliso Town. Your input is invaluable in understanding the current state of knowledge, awareness, and practice among construction stakeholders.

To participate in this, I would like to request your consent

If you are willing to participate, please I request you to sign here____________Date__________

All help is much appreciated. Thank you!

Please read the following instructions carefully before proceeding with the survey:

Rating Scale

You will be asked to rate various statements on a scale of 1 to 5. Each number on the scale corresponds to a specific level of agreement or frequency, as described below:

Knowledge

- **1 - Not Knowledgeable**: You have no knowledge about the topic.
- **2 - Slightly Knowledgeable**: You have minimal knowledge about the topic.
- **3 - Moderately Knowledgeable**: You have a fair amount of knowledge about the topic.
- **4 - Knowledgeable**: You have a good understanding of the topic.
- **5 - Highly Knowledgeable**: You have extensive knowledge about the topic.

Awareness

- **1 - Not Aware**: You are not aware of the topic.
- **2 - Slightly Aware**: You have minimal awareness of the topic.
- **3 - Moderately Aware**: You have a fair amount of awareness of the topic.
- **4 - Aware**: You are well aware of the topic.
- **5 - Highly Aware**: You have a high level of awareness of the topic.

Practice

- **1 - Never Practice**: You never engage in this practice.
- **2 - Rarely Practice**: You engage in this practice very infrequently.
- **3 - Sometimes Practice**: You engage in this practice occasionally.
- **4 - Often Practice**: You engage in this practice frequently.
- **5 - Always Practice**: You engage in this practice consistently.

Knowledge questions	5	4	3	2	1
1. Are you aware of the environmental regulations related to building construction?					
2. Do you know the benefits of using sustainable materials in construction?					
3. Are you familiar with the concept of green building certification?					
4. Do you understand the impact of construction activities on local ecosystems?					
5. Are you knowledgeable about energy-efficient building designs?					
6. Do you know the importance of waste management in construction projects?					
7. Are you aware of the water conservation techniques in building construction?					
8. Do you understand the role of renewable energy in sustainable construction?					
Awareness questions	**5**	**4**	**3**	**2**	**1**
1. Are you aware of the environmental impact of traditional construction methods?					
2. Do you recognize the importance of sustainable construction practices?					
3. Are you aware of the environmental policies implemented by local authorities?					
4. Do you understand the significance of reducing carbon emissions in construction?					
5. Are you aware of the benefits of green roofs and walls?					
6. 6. Do you recognize the importance of biodiversity conservation in construction projects?					
7. Are you aware of the environmental impact of construction waste?					
8. Do you understand the need for sustainable urban planning?					
Practice questions	**5**	**4**	**3**	**2**	**1**
1. Do you implement sustainable practices in your construction projects?					
2. Do you use eco-friendly materials in your construction projects?					
3. Do you follow waste management protocols on-site?					
4. Do you incorporate energy-efficient designs in your projects?					
5. Do you use water conservation techniques in your construction projects?					
6. Do you prioritize renewable energy sources in your projects?					
7. Do you engage in practices that minimize the environmental impact of construction?					
8. Do you ensure compliance with environmental regulations in your projects?					

Appendix C

Interview guide Questions for construction stakeholders to assess the knowledge, awareness, practice and factors affecting environmental sustainability in the study area.

Dear Participants,

Thank you for agreeing to participate in this interview. The purpose of this interview is to assess the knowledge, awareness, practices, and factors affecting environmental sustainability in building construction projects in Woliso Town. Your insights and experiences are crucial for understanding the current state of environmental sustainability practices among construction stakeholders. The information you provide will be used to identify areas for improvement and to develop strategies for promoting sustainable construction practices in the town.

Please answer the following questions based on your knowledge and experience. Your responses will be kept confidential and will only be used for research purposes.

To participate in this, I would like to request your consent

If you are willing to participate, please I request you to sign here____________Date__________

Thank you for your cooperation and valuable contribution to this study.

Interview Guide Questions

1. Are you familiar with the concept of urban heat islands and their potential impact on the town?
2. Have you noticed temperature variations, especially during hotter seasons, in your building?
3. Does your building have green spaces or green roofs to mitigate heat island effects?
4. What measures have you implemented to reduce heat absorption in your building (e.g., natural ventilation, shading, reflective materials)?
5. Do you believe vegetation plays a crucial role in mitigating heat island effects? If so, how?
6. Are you aware of the potential benefits of reducing reliance on municipal water and the associated cost savings?
7. Are you aware of your building's total water consumption? How do you monitor it?
8. Have you implemented any water conservation practices in your building (e.g., low-flow faucets, water-efficient appliances)?

9. Are there ongoing awareness campaigns to encourage responsible water use in your building?
10. Are you aware of the benefits of using energy-efficient lighting systems (e.g., LED, CFL)?
11. Are you aware of the energy consumption patterns in buildings in the town?
12. Have you implemented automatic lighting controls or occupancy sensors in common areas to reduce energy consumption?
13. What type of ventilation systems are used in your building (e.g., mechanical, natural)? How do they contribute to energy efficiency?
14. Are you aware of the importance of maintaining good indoor air quality?
15. Do you regularly assess the effectiveness of your building's ventilation system?
16. What measures have you implemented to ensure acceptable indoor air quality (e.g., regular cleaning, air purifiers)?
17. How do you manage noise levels in your building? Are there any noise reduction strategies in place?

JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

THESIS APPROVAL SHEET

I hereby, the undersigned, declare that this MSc thesis titled "Assessment of Environmental Sustainability of Building Construction: A Case of Woliso Town" was prepared under the guidance of **Dr. Lucy Feleke** and **Engr. Bontu Woyessa**. This was carried out by me and is my original work. Moreover, I confirm that the thesis has not been submitted, either in part or in full, to any other higher institutions for earning similar or any other degree awards.

Name of the student	**Date**	**Signature**
▪ Firikot Melaku	____________________	__________________

Advisors Name	**Date**	**Signature**
▪ Dr. Lucy Feleke	____________________	__________________
▪ Engr. Bontu Woyessa	___________________	__________________

Internal examiner	**Date**	**Signature**
▪ Engr. Frikot Mulatu	____________________	__________________

External examiner	**Date**	**Signature**
▪ Dr. Bayou Chane	____________________	__________________