

**Optimizing Key Performance Indicators and
Lifecycle Stages in the Iraq Construction Industry: A
Systematic Review and Generic Framework
Development**

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ABSTRACT

The objective of this study is to propose a generic framework, for constructing energy efficient high rise buildings in Iraq. This framework aims to address challenges and achieve long term sustainability goals. The development of this framework is based on an in depth analysis of 69 papers. Incorporates various sustainable indicators throughout different stages of the construction process. In the design phase the framework integrates elements such as incorporating energy using materials in construction implementing water conserving landscaping, smart irrigation systems and designing energy efficient ventilation systems. As the construction phase begins the framework also considers energy storage solutions like batteries and building automation systems to optimize energy usage and enhance efficiency. During the utilization phase several strategies can be employed to promote sustainability and improve efficiency. These strategies include implementing energy efficiency upgrades obtaining building certifications, recycling and reusing water resources minimizing waste generation through source reduction measures providing on site waste management facilities along, with segregation and sorting mechanisms conducting regular maintenance activities employing lighting control measures based on occupancy feedback and monitoring systems. By adopting these practices during the phase of high rise buildings life cycle can effectively contribute towards achieving goals related to energy efficiency improvement, emissions reduction, water conservation efforts while enhancing environmental quality.

During the phase of a products life cycle the framework combines circular economy initiatives. These initiatives aim to promote waste management and minimize impact.

The proposed generic framework holds significance as it enables progress in sustainability, within Iraq's high rise building construction sector. This contribution would be valuable in efforts to combat climate change and foster sustainable development. However successful implementation requires overcoming challenges such, as regulatory constraints, financial considerations, raising awareness and access to sustainable technologies.

Keywords: energy efficiency, building energy, high rise building, energy performance, key performance indicators, construction life cycle

ÖZ

Bu çalışmanın amacı, Irak'ta enerji verimli yüksek katlı binaların inşasını öneren genel bir çerçeve sunmaktır. Bu çerçeve, zorlukları ele almayı ve uzun vadeli sürdürülebilirlik hedeflerine ulaşmayı amaçlamaktadır. Bu çerçevenin geliştirilmesi, 69 makalenin derinlemesine analizine dayanmaktadır ve inşaat sürecinin farklı aşamalarında çeşitli sürdürülebilir göstergeleri içermektedir.

Tasarım aşamasında, çerçeve enerji kullanımını içeren malzemeleri inşaata dahil etme, su tasarruflu peyzaj düzenlemesi uygulama, akıllı sulama sistemlerini kullanma ve enerji verimli havalandırma sistemlerini tasarlama gibi unsurları sorunsuz bir şekilde entegre etmektedir. İnşaat aşaması başladığında, çerçeve aynı zamanda enerji depolama çözümlerini, bataryaları ve bina otomasyon sistemlerini enerji kullanımını optimize etmek ve verimliliği artırmak amacıyla dikkate almaktadır.

Kullanım aşamasında, sürdürülebilirliği teşvik etmek ve verimliliği artırmak için bir dizi strateji kullanılabilir. Bu stratejiler, enerji verimliliğini artırmayı, bina sertifikalarını elde etmeyi, su kaynaklarını geri dönüştürmeyi ve yeniden kullanmayı, kaynak azaltma önlemleri ile atık oluşturmayı en aza indirmeyi, ayrıştırma ve sıralama mekanizmalarıyla birlikte yerinde atık yönetimi tesisleri sağlamayı, düzenli bakım faaliyetlerini yürütmeyi, işgal geri bildirimine dayalı aydınlatma kontrol önlemlerini içermektedir.

Yüksek katlı binaların yaşam döngüsü aşamasında, bu uygulamaları benimseyerek enerji verimliliğini iyileştirme, emisyon azaltma, su koruma çabalarını güçlendirme ve

çevresel kaliteyi artırma gibi hedeflere etkili bir şekilde katkı sağlamak mümkün olabilir.

Ürün yaşam döngüsü aşamasında, çerçeve dairesel ekonomi girişimlerini birleştirir. Bu girişimler, atık yönetimini teşvik etmeyi ve olumsuz çevresel etkileri en aza indirmeyi amaçlar. Önerilen genel çerçeve, Irak'ın yüksek katlı bina inşaat sektöründe sürdürülebilirlik alanında ilerlemeyi mümkün kılarak önemli bir rol üstlenmektedir. Bu katkı, iklim değişikliğiyle mücadele ve sürdürülebilir kalkınmayı destekleme çabalarında değerli bir rol oynayacaktır. Ancak başarılı uygulama için düzenleyici kısıtlamalar, mali düşünceler, farkındalığı artırma ve sürdürülebilir teknolojilere erişim gibi zorlukların üstesinden gelinmesi gerekmektedir.

Anahtar Kelimeler: enerji verimliliği, bina enerjisi, yüksek bina, enerji performansı, temel performans göstergeleri, inşaat yaşam döngüsü

DEDICATION

I am dedicating this thesis to my Allah, to the Luck that have shaped my journey, and to my Family.

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LIST OF ABBREVIATIONS

ARP	Adaptive Reuse Potential
BAS	Building Automation Systems
BREEAM	Building Research Establishment Environmental Assessment Method
BIM	Building Information Modeling
CTBUH	Council on Tall Buildings and Urban Habitat
ECBC	Energy Conservation Building Code
ECM	Electronically Commutated Motors
EI	Energy Efficiency Index
EPA	Environmental Protection Agency
EUI	Energy Use Intensity
HRVs	Heat Recovery Ventilators
HVAC	Heating, Ventilation and Air Conditioning
IBC	International Building Code
IEA	International Energy Agency
IEQ	Indoor Environment Quality
ISO	International Organization for Standardization
KPI	Key Performance Indicators
LEED	Leadership in Energy and Environmental Design

Chapter 1

INTRODUCTION

1.1 Introduction

Buildings consume a significant amount of energy throughout their life cycles, with the building sector accounting for 40% of all carbon dioxide emissions globally and 36% of final energy usage (Li, 2008). Despite the need to reduce energy consumption by 30% on average to help mitigate the effects of global warming and climate change by 2030 (Abergel et al., 2017), there has been a continued increase in energy consumption in buildings over the years. This demonstrates the urgent need to improve energy efficiency in buildings in order to improve the sustainability of societies and the natural environment. Various energy efficiency measures could be employed during the design of new buildings as well as in existing ones, such as building operating techniques, photovoltaic integrated energy storage systems, ventilation and air conditioning systems, and high-performance heating systems.

However, conventional methods of building energy performance assessment are often limited in their ability to identify the various issues that could affect the efficiency of energy consumption in a building. These conventional methods are typically statistical, where data on various features contributing to the building's performance is collected and analyzed through questionnaire surveys, energy bills, and field tests. These approaches tend to ignore the short-term energy consumption behaviors of occupants, making the data lack feasibility as a reliable tool to measure efficiency. Additionally,

the conventional methods usually establish linear relationships in their models, ignoring the non-linear relationships that exist between the variables in question and the energy consumption within a building. Therefore, there exists a dire need to have more methods of energy assessment to ensure that the buildings constructed are energy-efficient and are following the required codes within a jurisdiction.

Energy performance assessment of high-rise buildings has become a critical area of research due to the increasing energy consumption of these buildings worldwide. Iraq, the need for energy-efficient high-rise buildings is crucial, as the region experiences a severe climate characterized by long hot summers and cold winters. The construction of high-rise buildings has been on the rise in the region due to population growth, urbanization, and economic development. However, these buildings consume a significant amount of energy, contributing to environmental degradation, increasing operational costs, and reducing the quality of life for building occupants. According to research done in Iraq, energy consumption in high-rise structures may account for up to 70% of overall energy consumption in the area (Raof B. 2017).

The development of energy-efficient high-rise buildings in Iraq is difficult due to a variety of reasons, including a lack of awareness, limitations availability of technology, an insufficient regulatory framework, and inadequate funding. Studies have shown that worldwide there is a lack of awareness among building owners and occupants regarding the importance of energy-efficient buildings (Fouad et al., 2019). Furthermore, the limited access to technology and insufficient financing hinders the adoption of energy-efficient measures in high-rise buildings. In Iraq, the lack of a comprehensive regulatory framework to promote energy-efficient high-rise buildings has resulted in the construction of buildings that do not meet the required energy

standards. A study conducted by Amin et al. (2019) in Iraq found that the energy efficiency regulations in the country were inadequate and required significant improvements to promote energy-efficient buildings.

The lack of energy-efficient high-rise buildings in Iraq has significant environmental and economic consequences. The high energy consumption of these buildings contributes to environmental degradation, air pollution, and greenhouse gas emissions. The operational costs of these buildings are also high, leading to increased expenses for building owners and occupants. Furthermore, the energy inefficiency of high-rise buildings reduces the comfort and productivity of building occupants. Studies have shown that energy-efficient buildings enhance indoor air quality, reduce noise pollution, and improve the overall well-being of occupants (Sassi et al., 2021). Therefore, there is a need to promote energy-efficient high-rise buildings in Iraq to mitigate environmental degradation, reduce operational costs, and enhance the quality of life for building occupants.

1.2 Scope and Objectives

The scope of this study is to conduct a comprehensive review of the literature on energy efficiency and sustainability assessment of high-rise buildings in Iraq. The study will focus on identifying the different approaches used to evaluate the energy consumption and efficiency of high-rise buildings in the region, as covered in previous literature. The scope of the study also includes a review of the sustainability examination approaches of high-rise buildings available in various research studies. Besides, the study was limited to published articles and academic journals within the past 10 years in English and accessed through the six selected databases. The scope of this study does not include unpublished research or gray literature, nor does it cover

case studies or specific technical methods for conducting energy assessments. The study will provide a general overview of the methods, tools, and techniques used to evaluate energy efficiency and sustainability in high-rise buildings in Iraq. The following were the study objectives:

1. To review and evaluate the diverse energy efficiency approaches in high-rise buildings in the existing literature.
2. To develop a generic framework that integrates specific Key Performance Indicators (KPIs) with the purpose of fostering sustainable practices and facilitating decision-making across all phases of high-rise building construction in Iraq.
3. To evaluate the primary challenges and obstacles encountered in the execution of the suggested KPI-based generic framework for sustainable high-rise building construction in Iraq and developing efficient strategies for reducing these challenges in order to guarantee the successful adoption and implementation of the framework.

1.3 Methodology

This study's objective was to thoroughly evaluate the literature on high-rise building energy efficiency assessment. Research Gate, Google Scholar, JSTOR, Wiley Online, Taylor & Francis, and Elsevier were all thoroughly searched to do this. Search terms such as "efficient measurement of building energy," "building energy performance measurement," "building energy assessment," and "building energy efficiency evaluation" were used to locate data on building energy performance assessment in high-rise buildings. The researcher used criteria to locate just those papers published in English, Turkish and Arabic during the previous ten years, except for key works written before 2012. The reference list discovered in a certain database was examined first to check the source's validity before deeming an article appropriate for usage.

Three main steps made up the search process: scanning the titles, keywords, and abstracts of the articles found through related search terms; reviewing the abstracts of the papers to weed out those not directly relevant to the search topic; and creating a list of the articles found that contained information specifically about energy efficiency measurement so that they could be further analyzed. Finally, 69 relevant publications were selected and examined in this study, and the findings are provided in Chapter 3. This study sought to offer an overview of the present state of research on energy performance evaluation of high-rise buildings and recommend areas for further research and development in this area by thoroughly examining and analyzing the literature.

1.4 Research Questions

1. What are the energy efficiency and consumption evaluation approaches and themes identified within the publications on the evaluation of the energy performance of high-rise buildings as covered in previous literature?
2. How can a comprehensive framework, encompassing specific Key Performance Indicators (KPIs), be formulated to provide guidance for sustainable practices and decision-making across all stages of the life cycle of high-rise building construction in Iraq?
3. What are the main challenges and obstacles encountered in the implementation of the suggested Key Performance Indicator (KPI)-based generic framework for sustainable high-rise building construction in Iraq, and how can these challenges be effectively mitigated to ensure a successful adoption and implementation?

1.5 Achievements

The article examines the evaluation of energy performance in high-rise buildings throughout their life cycle, encompassing four distinct stages: product stage,

construction stage, use stage, and end-of-life stage. The research findings suggest that prior studies primarily concentrate on the utilization and production phases, with comparatively less attention given to the construction and end-of-life phases. The selection of materials in the design stage significantly influences a building's energy performance throughout its life cycle. The utilization phase exhibits the most substantial ecological footprint, primarily attributed to the consumption of operational energy, which constitutes approximately 80% to 90% of the overall environmental impact. Comparative analyses demonstrate variations in energy consumption across different life cycle stages and types of buildings. This study emphasizes the importance of incorporating the complete life cycle of a building into energy performance assessments in order to promote sustainable building practices.

The systematic review analyzed 69 articles on key performance indicators (KPIs) for assessing high-rise buildings' energy efficiency and environmental performance. The KPIs encompass five distinct sub-themes, namely energy, emissions, water, waste, and indoor environmental quality (IEQ). The results showed that energy, emissions, water, and waste are the most important factors. The energy parameter was the most dominant theme, followed by emissions and water. The findings also indicated that the indoor environment quality was the least focused areas. The reviewed articles mainly studied energy and emissions in commercial, public, and residential buildings. HVAC systems and lighting were found to be the most dominant factors in energy consumption. Overall, the study highlights the importance of considering KPIs to assess high-rise buildings' energy efficiency and environmental performance.

1.6 Research Novelty

The study significantly advances the fields of energy efficiency and sustainable building design. The new study focuses exclusively on high-rise structures that differ from other structures in their energy performance. The research measures the energy efficiency of high-rise buildings using a wide range of energy performance metrics, such as energy consumption per unit area, energy consumption per occupant, and energy intensity. The study's significance is in its capacity to offer practical insights into the design and operational approaches that may be used to enhance high-rise buildings' energy performance.

One of the study's drawbacks is that it only considers energy performance, ignoring other crucial elements of building design and operation, such as occupant comfort and interior environmental quality. Energy efficiency is unquestionably crucial to the design of sustainable buildings, but it is just one part of a more comprehensive strategy. More investigation into the interactions between energy efficiency, interior environmental quality, and occupant comfort in high-rise structures would thus be useful. The research's conclusions are also based on a single case study, which could not be representative of other high-rise structures. Conducting multiple case studies in different locations and with different building types would provide a more comprehensive understanding of the factors that influence energy performance in high-rise buildings.

1.7 Guide to Thesis

The literature review in Chapter 2 summarizes the theories and research that have been done in relation to the thesis subject. It identifies any knowledge gaps the study seeks to fill and offers the major results and discussions on the subject. The research design,

data-gathering techniques, and analytical tools are discussed in chapter 3's methodology section. It discusses why these approaches were chosen and how they fit the study's goals and questions. The study's findings are presented in Chapter 4, the results and analysis chapter, and any statistical analyses and data visualizations. It also contains a discussion of the ramifications and importance of the results. The discussion chapter, Chapter 5, summarizes and discusses the study's results and contextualizes them in light of the body of prior research. It highlights the study's advantages and disadvantages, points out any fresh ideas, and offers suggestions for further investigation. The important findings, their ramifications, and the study's contribution to the field are summarized in Chapter 6, which serves as the conclusion and recommendation chapter. The research finishes with suggestions for practitioners and policymakers based on its findings.

Chapter 2

LITREATURE REVIEW

2.1 Overview of the International Community on Energy Efficiency

The issue of energy efficiency came to light at the global level after the 1973's global energy crisis. During this year, Saudi Arabia led the members of the Organization of Arab Petroleum Exporting Countries to proclaim an embargo to target the states that had supported Israel in the Yom Kippur War. After this crisis, the world started thinking of how energy could be conserved because of the possibility of a depletion to the energy resources in the foreseeable future. Energy consumption in buildings was a major way to slow down exploitation of energy resources. The USA built the first ever experimental building to test and identify the ideal technical approaches to save energy in buildings (Zhigulina and Ponomarenko, 2018). The building's rate of energy consumption was regulated through computer control of its engineering equipment, double-layer fencing structures, and efficient use of solar radiation (Generalov, 2007). This project initiated global efforts of constructing energy efficient structures. Construction of buildings with high energy efficiency has successfully been achieved in many parts of the world including Europe, the Middle East, and in other third world countries that are environmentally conscious. Denmark, Germany, and Finland are the leaders in Europe, with Saudi Arabia, Morocco, Kuwait, and Tunisia leading the Middle East in efforts to produce energy efficient buildings (Zhigulina and Ponomarenko, 2018). Such countries and others that are environmentally conscious have state programs to help in construction of energy saving and energy efficient

buildings. In the contemporary world, energy conservation has been changed to be referred to as energy efficiency because it not only involves conserving energy but also using cleaner sources of energy. The major principle of energy efficient buildings is using cleaner energy sources which are renewable such as wind, sun, and earth's thermal energy.

Several energy rating systems have been adopted by different countries and international organizations to rate buildings' environmental and energy performance. These rating systems form the quality standards of the contemporary construction industry. The most commonly used ones are the US system LEED (Leadership in Energy and Environmental Design) introduced in 1998 and the British BREEAM (Building Research Establishment Environmental Assessment Method) introduced in 1990. The two methods are much similar, but the BREEAM approach usually has to do with the assessment of ecological efficiency. However, LEED approach is usually concerned about energy efficiency of buildings (Roderick et al., 2009). LEED is usually rigid and can only be used within USA as it follows strict material certification and evaluation standards in the country. On the other hand, BREEAM is flexible and adaptable to local construction practices and norms.

2.2 International Definitions of Energy Efficiency

As per the International Energy Agency (IEA), energy efficiency in buildings revolves around the skillful utilization of energy to achieve reduced consumption while preserving or enhancing comfort, productivity, or services (Scott & Gössling, 2021). The primary focus lies in diminishing energy use without compromising occupants' well-being or the building's functionality. Energy-efficient buildings deploy diverse strategies, technologies, and design principles to curtail energy waste and optimize

energy utilization for heating, cooling, lighting, appliances, and other energy-consuming systems (Saini et al., 2022). These encompass enhanced insulation, energy-efficient windows, top-notch heating and cooling systems, LED lighting, smart energy management systems, and more. Ultimately, the overarching objective remains curbing energy demand and reducing greenhouse gas emissions within the building sector. Throughout a building's entire life cycle, the International Energy Agency (IEA) definition highlights the significance of energy efficiency. It emphasizes the need for building design, construction practices, and operational techniques to attain energy efficiency in buildings.

On the other hand, the U.S. Environmental Protection Agency (EPA), entails accomplishing equal services with less energy. The EPA's definition aligns with the overarching notion of energy efficiency, where the focus lies in sustaining the same output or service while curbing energy consumption. Central to this concept is employing technology and practices that minimize energy waste and optimize energy utilization, ultimately translating to reduced costs, diminished environmental impact, and heightened sustainability (Curtis & Lee, 2019). Demonstrated by the example of a compact fluorescent bulb, energy-efficient technologies can remarkably slash energy consumption in comparison to less efficient alternatives while delivering equivalent services (in this instance, lighting).

2.3 Classification of Building Energy Efficiency Measures

Sustainable development depends on incorporating energy practices to minimize energy consumption and environmental consequences. In the field of academia there are two metrics, for assessing energy efficiency. Active measures involve utilizing equipment and processes that consume amounts of energy while passive measures

focus on leveraging building design and natural resources to enhance energy efficiency.

2.3.1 Active Measures

Active measures involve technologies or systems reliant on external energy inputs to function. They actively consume energy to provide specific services like heating, cooling, lighting, or electricity generation.

1. Heating, ventilation and air conditioning (HVAC) systems are crucial, for optimizing building energy usage. These systems utilize technologies like heat pump systems, variable speed motors and smart control strategies to ensure indoor comfort while reducing energy consumption. Energy efficient HVAC systems play a role, in minimizing energy waste and achieving energy savings by effectively managing the distribution of heated or cooled air based on building occupancy and external weather conditions (Li et al., 2020).
2. Revolutionizing the lighting industry, LED lights exhibit remarkable energy efficiency by converting electricity directly into light with minimal heat loss. Compared to traditional incandescent bulbs, LED bulbs consume significantly less energy, boast an extended lifespan, and come in various colors and designs, making them a popular choice for energy-conscious building owners (Azimi Fereidani et al., 2021).
3. Building automation systems (BAS) make use of controls, sensors and algorithms to effectively manage building operations such, as lighting, HVAC and security systems. These systems enable adjustments based on occupancy patterns, temperature changes and other factors to ensure energy usage. By centralizing and

automating building operations BAS minimizes energy waste, leading to energy efficiency and enhanced comfort, for occupants (Dino & Meral Akgül, 2019).

4. The integration of renewable energy systems, like solar panels or wind turbines, facilitates electricity generation from renewable sources. Solar panels convert sunlight into electricity, while wind turbines harness wind energy. Although these systems necessitate initial energy inputs for production and installation, they offer long-term energy savings, decreasing dependence on fossil fuel-based electricity and promoting a more sustainable and eco-friendly energy supply. (Dehwah et al., 2020)

2.3.2 Passive Measures

Passive measures embrace building design and material choices that capitalize on natural phenomena, bolstering energy efficiency without depending on external energy inputs. Their essence lies in optimizing factors like insulation, building orientation, natural ventilation, and daylighting, culminating in a passive reduction of energy consumption while sustaining a comfortable indoor environment.

1. Efficient insulation and strategic building orientation are essential factors in maintaining comfortable indoor temperatures and minimizing heat transfer. Incorporating high-quality insulation materials in walls, roofs, and floors accomplishes this goal. Additionally, positioning windows and shading devices thoughtfully optimizes solar heat gain in winter and reduces it in summer, thereby decreasing the reliance on heating and cooling systems. (Li et al., 2020).
2. Natural ventilation is another integral aspect. When buildings are designed with well-placed windows, vents, and openings, natural airflow and cross-ventilation

come into play. This allows fresh air to circulate, eliminating stale air and lessening the need for mechanical fans or air conditioning. Not only does it conserve energy, but it also elevates indoor air quality and enhances occupant comfort. (Hughes et al., 2012)

3. Daylighting is yet another noteworthy consideration. By incorporating ample windows, skylights, and light shelves in building design, the utilization of natural sunlight is maximized. This approach lessens the dependence on artificial lighting during the day, thereby conserving energy and establishing a more pleasing and productive indoor setting. (Nageib et al., 2020)

4. Increasing a building's energy efficiency may be accomplished via the implementation of a number of different practices that cut down on energy use and foster a more sustainable environment. According to Aste and Morello (2018), technological methods concentrate on modernizing building components such as insulation, HVAC systems, and lighting in order to enhance energy efficiency. Implementing energy management systems and taking part in demand response programs are examples of operational strategies that may help maximize the efficiency of energy use (Wang et al., 2021). According to Hong et al.'s research from 2020, design and planning strategies should place an emphasis on passive design principles and the integration of renewable energy systems in order to lessen dependency on non-renewable resources. (Gladysz et al., 2019) Behavioral measures concentrate on occupant participation and education via the use of energy awareness programs and guidelines.

According to Gupta and Gupta's research from 2020, efficient building envelope renovations, which include insulation and air sealing, help to reduce heat loss or gain, which in turn reduces the demand for mechanical heating or cooling systems in the building. According to Ming et al.'s research from 2020, modernizing HVAC systems with high-efficiency technology such as heat pumps may drastically cut energy usage while maintaining the same level of comfort. According to Crawley et al.'s research from 2020, installing lighting solutions that are more energy-efficient, such as LED technology and occupancy sensors, may result in significant energy savings in buildings. These technology solutions are geared on improving building energy performance and making more efficient use of energy inside structures.

Operational measures entail the establishment of energy management systems for tracking and controlling energy-consuming devices and systems in buildings (Wang et al., 2021). These systems monitor and regulate energy-consuming devices and systems within buildings. According to Wang et al. (2021), such systems offers real-time data on consumption of energy, which enables facility managers to discover inefficiencies and maximize the effectiveness of building operations. Buildings may contribute to grid stability and alleviate pressure on the power system by lowering their energy usage during times of peak demand by taking part in demand response programs, which Wang et al., 2021 explains will enable them to do so. These strategies optimize energy use depending on demand and the needs of daily operations, which contributes to increased energy efficiency.

According to Hong et al.'s research from 2020, design and planning strategies should put an emphasis on passive design concepts such as the strategic orientation of buildings and the positioning of windows to maximize natural light, solar heat gain,

and ventilation. Buildings that make use of renewable energy systems, including solar photovoltaics or wind turbines, are better equipped to meet their own energy needs via the production of clean energy on-site (Li & Wu, 2020). These solutions improve energy efficiency while simultaneously lowering reliance on power generated by fossil fuels.

The engagement of residents and the provision of knowledge about energy-saving methods are the primary focuses of behavioral measures. According to Gladysz et al. (2019), awareness about energy campaigns and occupant education sessions improve understanding about energy-saving practices and provide occupants with information on sustainable appliance use, thermostat settings, and the need of shutting off lights and equipment whenever not in use. These methods help to better energy efficiency in buildings by encouraging individuals to engage in environmentally responsible activities and to reduce their energy use.

2.4 Definitions of High Rise Building

There is no internationally recognized definition of the word high-rise building and thus, the term can have different definitions depending on the location in question (Farouk, 2011). For instance, a five-storey building in the midst of bungalows will easily be seen as a tall building in that particular neighborhood. The following are some definitions from different authors and international organizations.

Taranath (2009) asserted that a high-rise building could be described as so with regard to the specific storey height or number of floors, but the line of division should be ought to be where the structural design moves from the field of statics to structural dynamics.

Nguyen et al. (2019) defined a high-rise building as a “any structure where the height can have a serious impact on evacuation” (p. 1).

Craighead (2009) hold that “for most purposes, the cut-off point for high-rise buildings is around seven stories. Sometimes, seven stories or higher define a high-rise, and sometimes the definition is more than seven stories. Sometimes, the definition is stated in terms of linear height (feet or meters) rather than stories” (p. 1).

Fay (2007) asserts that “a high-rise structure is considered to be one that extends higher than the maximum reach of available fire-fighting equipment. In absolute numbers, this has been set variously between 75 feet (23 meters) and 100 feet (30 meters) or about seven to ten stories (depending on the slab-to-slab distance between floors” (p. 85).

Section 202 of the 2015 International Building Code (IBC) defines a high-rise building as a building whose occupied floors are at least 75 feet above the lowest level which can be accessed by the fire department vehicles.

Council on Tall Buildings and Urban Habitat (2016) considered a high-rise building as one that is higher than other buildings in the surroundings or when its proportion is slender enough to provide an appearance of a tall building.

According to the report, buildings that have are 300-600m high may be regarded as Supertall Skyscrapers while those above 60m are regarded as Megatall Skyscrapers.

Other than what scholars and international organizations have to say about the meaning of a high-rise building, it is common for communities, standards organizations, regulatory bodies, and municipals to create their own meanings and standards of what a high-rise building actually is within their respective jurisdictions.

In India, for example, the National Building Code of India defines high-rise building as one that has a height of more than 15m which is at least 5 storey (Agrawal, 2022).

Generalov et al. (2018) hold that the Russian definition of a high-rise building is one that is above 75m high.

Council on Tall Buildings and Urban Habitat (CTBUH) has established specific height criteria to categorize buildings into different classifications:

For "High-Rise Buildings," CTBUH sets the threshold at 150 meters (approximately 492 feet) in height. This measurement is taken from the lowest, significant, open-air, pedestrian entrance to the architectural top, incorporating spires, while disregarding antennae, signage, flagpoles, and other functional-technical equipment (Memon et al., 2020).

Moving further, "Supertall Buildings" receive their classification if their height surpasses 300 meters (approximately 984 feet).

From these various definitions, what can be said about high-rise buildings is that they are tall buildings rising well above the average structure height in any given market. The definition is subjective and relative to a particular market with the specific number

of minimum stories that it should contain ranging from as low as 5 to as many as several tens of them.

2.5 Types of High Rise Buildings Structures and their Material Properties

The structural system of a high-rise building is built for coping with gravity loads occurring vertically and the lateral ones brought about by seismic movements and winds (Mele et al., 2014). It consists only of the elements that are designed to withstand the loads and the rest are regarded as non-structural. To determine the structural system in a high-rise building, Chung and Sunu (2015) say that the engineer needs to select and arrange the major structural elements which can efficiently resist a combination of the lateral forces and vertical loads. A high-rise building should be as stable as possible, and the right materials should be selected to maximize the flexural rigidity.

2.5.1 Timber

Sartori and Tomasi (2013) hold that the main structural systems employed in building timber structures are basically on panel construction elements and they could be made of cross-laminated timber panels or lightweight wood frame panels. In either of the systems, structural systems may be considered as a building's envelop and still have a load-bearing function at the same time (Piazza et al., 2005). Such structural systems are made by utilizing prefabricated modular elements built in a factory, and later mechanically connected on site. Wood has various disadvantages to use as a structural system in high-rise building including minimal serviceability, earthquakes or acoustic and vibrations, and not meeting the minimum requirements on fire protection (Frangi and Fontana, 2005; Gerard et al., 2013; Piazza and Tomasi, 2013). To counter these drawbacks, wood is usually mixed with other materials to form hybrid systems.

2.5.2 Concrete

In high-rise buildings, reinforced concrete is the form of concrete that is usually used because of its ability to resist the vertical and horizontal loads as compared to plain concrete. The main difference is that the reinforced concrete is entirely freestanding columns held together with horizontal beams at every floor level. The framing is relevant high-rise buildings with the beams and columns standing a chance to be designed to tolerate almost unlimited weight exerted by the dead loads of the structure, wind, and the occupants. The frame is highly flexible for the floor adjustments in the future because there are only a few masonry bearing walls to relocate or remove (Kuzmanovska et al., 2018). Concrete frames are usually prepared on site and poured floor by floor as the construction proceeds. If beams become an aesthetic or functional issue, then a slab floor system is created to eliminate beams through thickened floor construction. Nuaklong et al. (2021) says that concrete has an advantage over wood in that it is fireproof and thus there are no other extra mechanisms needed to meet fire safety and exit codes for high-rise buildings.

2.5.3 Steel

Steel-framed buildings are much like the concrete ones in that the framing depends on a post-and-beam mechanism in designing, and is made as a solo structure prior to the placement of the exterior walls (Koshihara, 2021). The advantage that steel structures have over concrete is that they are easier to work with in winter conditions and also can be erected faster. They are raised using rivets, bolts, welds, or using more than one technique (Csernak and Csernak, 2012). Steel is prone to damage by fire if the temperatures rise above the metal's melting point. Besides, it does not offer the same rigidity as concrete does and which may be needed for a high rise building.

2.5.4 Hybrid

Hybrid systems are used as a counter to the drawbacks experienced while using one of the structural types, making it ideal for the high-rise buildings (Smith and Frangi, 2014). Particularly, architectures and researchers have been much interested in the establishment of the wood-based structural systems in a rush to acquire the most energy-efficient solutions for high-rise buildings because they could otherwise be much energy-intensive. There are many forms of steel-timber designs that could be created and that has already been created. Loss et al. (2016) says that although hybrid structures have become common in the contemporary high-rise buildings, there is limited knowledge about them and thus they are not as widely used.

2.5.5 Material Properties of High-rise Building Structures

The three most important physical properties of a building material are shape, physical density, porosity, and durability. When it comes to shape, steel makes the best choice for high-rise buildings because it is ductile and can be made into different shapes without losing its toughness. However, wood and concrete cannot change their shape to fit the desired engineering features. In addition, density differs across the three materials. Wood is the least dense as compared to steel and concrete; the higher the density of a material, the more durable it is. The density of some wood differs in different tree species and how the timber is treated. However, its low density and porosity relative to concrete and steel reduces its durability. Its durability is also compromised by the fact that it's vulnerable to extreme weather and bugs such as termites, powderpost beetles, carpenter ants, carpenter bees, bark beetles and wood borers. Therefore, they might not be as reliable as steel or concrete in designing structures for high-rise buildings.

The mechanical properties of a building structure include impact strength, fatigue, stiffness, creep, brittleness, ductility, toughness, hardness, plasticity, elasticity, and strength. Out of the three materials, steel has the highest strength/weight ratio which ultimately makes the deadweight of high-rise structures made of steel to be smaller than that of timber and concrete. (Hegeir et al., 2022) Therefore, steel is a perfect choice in high-rise buildings because it can last longer particularly in areas with high seismic activities and in low soil bearing. Steel can undergo large plastic transformation before losing its strength and is important in that it can help in the resistance of shock loads such as earthquakes and blasts (Cai et al., 2021). On the other hand, wood has some degree of elasticity but no plasticity. Besides, steel has the highest strength-to-weight ratio, making it the best choice of all the construction materials. Neeladharan et al. (2018) hold that concrete has a relatively constant elasticity, but up to particular stress levels after which it starts to decrease and the matrix cracking begins. Tension and shrinkage assures that every concrete structure will crack at some point particularly due its low coefficient of thermal expansion.

The thermal properties of a construction structure describe its rate of heat transfer between the inside and outside of a building, the amount of heat absorbed on the surface through radiation or conduction, and the amount of heat that the material can store (Kalogirou, 2013). Wood is regarded as the best material in thermal resistance. When timber has been dried to standard levels of moisture content, it is able to resist heat flow which acts as a perfect insulation and thus best in building energy-efficient high-rise buildings among the three construction materials. The dimensions and strength of wood is not easily affected by heat changes and thus provides high stability even in adverse weather conditions. This is unlike steel which is a good conductor of

heat and like concrete, steel structures need continuous insulation to increase their energy-efficiency.

The most chemical property of a construction material is corrosion resistance which refers to the ability of a structure or material to withstand the action of oxidizing and corroding alkali or acidic gases and water. Steel, like any other metal tends to be corrosive to acid rain as well as oxidation. Steel is an alloy of iron and carbon, and it eventually rusts when exposed to air and moisture. Extra treatment, such as addition of chromium to make stainless steel offers a shield against rusting, but the material will still oxidize over time but at a very slow rate. Concrete, on the other hand, is less corrosive than steel and is only vulnerable to moisture and external chlorides. Out of the three materials, wood structures are the best corrosion resistant; wood is resistant to corrosion by acid, but remains vulnerable to alkalis (Zhang et al., 2021).

Engineers leverage the physical properties of construction material to reduce noise impacts in a structure. Overall, porous, pliable, and soft materials act as perfect acoustic insulators to absorb sound while hard, dense, and impenetrable materials like metals reflect most of the sound waves. Therefore, it can be noted that the most important factors which can help a material in becoming resistant to noise are rigidity and mass. Therefore, this makes wood the best choice when it comes to the provision of acoustical privacy because of its high porosity relative to steel and concrete with immense air spaces that can trap sound. Wood has a lower mass and density and thus is not great at blocking sounds. Second on the list is concrete which is highly efficient compared to steel but less efficient as compared to wood (Asdrubali et al., 2017). Walls and floors made of concrete materials perform appreciably when it comes to acoustic insulation because it can stop high sound waves which are less resistant to less massive

materials. In hybrid structures, wood could be added to the interior walls to increase its massiveness. In such an instance, plywood is commonly employed in multilayer in the interiors to help in soundproofing. Wood is usually used in the rooms where optimal sounding is needed (Wegst, 2006). Wood can resonate easily, and this enhances sound absorption, reflecting some and having the rest absorbed into the material. Based on its structure and performance, steel structures form the least efficient structures when it comes to acoustics. Sound can be transferred through the material just like any other metal because it is able to carry sound vibrations within itself. Such sound is referred to as structure-born vibration (Lu, 2008). In this light, poorly performing structures such as steel are combined with other materials such as wood to enhance its acoustical properties or treated with insulating materials such as rockwool, fiberglass, and foam (Berardi and Naldi, 2017). The insulating materials must have high sound absorbing properties to be considered for use in high-rise buildings. The materials tend to absorb sound by reducing the velocity of the particles carrying sound waves in the air.

Overall, comparing wood, steel, and concrete, wood forms the best choice in terms of acoustical performance of high-rise building structures. The solid mass of timber in high rise buildings reduce sound transmission between floors and walls. In general, this comprises of increasing mass where possible. It could mean engineers employing hybrid mass timber building system to make high-rise building structures which include combining wood and other building materials such as concrete toppings. Since most building codes prohibit the use of timber in making high-rise building structures, wood is used as a treatment when other materials are used to mitigate noise transfer.

Physiochemical properties include hygroscopicity, shrinkage, and swell because of changes in moisture content. Steel does not have internal pores and thus is not hygroscopic, meaning it does not pick up moisture from the water vapor or rainwater in the air. Steel can only get oxidized and rust when exposed to the environmental conditions such as moisture and air. Therefore, only concrete and wood are hygroscopic because of their porosity properties. On its side, wood can absorb water as vapor from the surrounding environment or as a liquid when it comes to contact with it. As such, without proper treatment, wood tends to absorb water in its liquid and gaseous forms. When this happens, water tends to affect a majority of other wood properties including plasticity, strength, and durability.

The riskiest part of having water absorbed by wood as a construction material is that it undergoes dimensional changes when it reaches the saturation point of the fiber (Carll and Wiedenhoft, 2009). When that moisture is lost, the wood shrinks and swells leading to the alteration of tangential, radial, and axial directions. This means that the amount of swelling and shrinkage that occurs in a timber is almost proportional to the change in the moisture content of that particular wood, but the degree depends on the wood species. The dimensional changes that occur as the timber shrinks and swells leads to tightening or opening of joints, collapse due to the distortion of the material, honeycombing as the timber dries after exposure to moisture, casehardening which results into warping, checking, and the alteration of cross-sectional shape (Raj and Lal, 2013; Spear and Walker, 2006). As such, the fact that wood can shrink, and swell is among the greatest obstacles that make wood unfit for use as a construction material in high-rise buildings because they are built to last over an extended period.

Some approaches have been developed to enhance the dimensional stability of wood for its use in building high-rise building structures, but it has to be used with other building materials. They include chemical and thermal treatment, bulking treatment where the wood is maintained in a swollen condition through the use of substances such as synthetic resins, polyethylene glycol, salts, and sugars, using water-repellent coatings such as varnish or paint, and mechanical modifications where it is reconstructed into such products as fiberboard, particleboard, and plywood. All the methods are either sufficiently costly or experimental which limit their use except for surface coating and the reconstruction into other products. Varnish and paint cannot reduce the moisture content that timber can hold but when applied, they help in reducing moisture exchange between the inside of the timber and the environment (Spear and Walker, 2006). This in turn helps to reduce the dimensional problems of the wood structure. Experts recommend that when wood is being used in making a building structure, it ought to have a moisture content at the approximate midpoint of the predicted range of a given place. Ultimately, this reduces the adverse impact of shrinkage and swelling.

Unlike wood, concrete is more efficient in preventing water absorption because its particles are more closely packed than that of wood. Therefore, concrete is the to-go-to material in areas with high humidity. Because of its high porosity, wood is more susceptible to damage by water and precipitation than concrete. It is possible to make different types of concrete depending on the measure of the materials used in making the material. During the hardening process, a sponge-like quality is created. While it could appear smooth, flat, and solid to the naked eye, but in the actual sense it has micropores that easily allow water into the material (Yi et al., 2014). The pores are made during the blending and curing process. Some of them could be found

superficially while others are found at the core of the material which makes it possible for a concrete structure to hold a high amount of moisture. During the curing process, the water used in making the concrete escapes from the paste. As the water escapes, it leaves behind bubbles behind and arrangement of little air pockets and passages inside the material. This makes the concrete porous with loads of voids that can soak water.

2.6 Classification of Energy Efficiency Measures in High Rise Buildings

Energy efficiency is an important aspect of sustainable building design, as it helps reduce energy consumption, costs, and greenhouse gas emissions. There are various categorizations and perspectives of energy efficiency approaches in buildings, including passive and active systems. This literature review will explore the different categorizations and perspectives of energy efficiency approaches in buildings.

2.6.1 Active Measures

On the hand active systems involve means to actively manage energy consumption. These systems rely on electricity or other energy sources. Are generally more costly to install and maintain compared to systems. Zhang et al. (2020) mention that active systems include HVAC (heating, ventilation and air conditioning) systems, lighting controls as renewable energy solutions like solar panels or wind turbines. HVAC systems are responsible for heating, cooling and ventilating buildings while striving for optimal efficiency levels to minimize energy usage. Lighting controls such as occupancy sensors and daylight sensors automatically turn lights on/off based on space occupancy and light availability. Renewable energy solutions generate electricity using resources which can potentially reduce or even eliminate reliance, on grid supplied power.

Retrofitting is when you upgrade existing buildings to make them more energy efficient. As, per Song et al. (2020) retrofitting is a cost method to enhance energy efficiency, in older buildings that weren't originally designed with energy efficiency in mind. Adding insulation replacing windows upgrading HVAC systems and installing energy lighting are some examples of retrofitting.

Energy management encompasses the utilization of technology and data analysis to optimize the use of energy, in buildings. As explained by Zhang et al. (2020) energy monitoring systems, building automation systems and smart controls for lighting and HVAC are some examples of energy management techniques. These systems enable the monitoring of energy consumption, identification of areas with inefficiencies and real time adjustments to building systems to minimize energy usage.

Building codes and standards are measures that ensure a level of energy efficiency in both new constructions and existing buildings. Tukker et al. (2019) provide examples such as the Energy Conservation Building Code (ECBC) in India and the International Energy Conservation Code (IECC) in the United States. By enforcing these codes all buildings can meet a standard of energy efficiency.

Behavioral approaches involve modifying the habits and actions of building occupants to reduce their energy consumption. Zhang et al. (2020) suggest practices, like using stairs of elevators turning off lights when leaving a room and setting thermostats to energy saving temperatures as behavioral strategies. When combined with energy efficiency methods behavioral approaches can significantly contribute to reducing energy consumption.

The role of thermal bridging and airtightness in preventing heat loss and decreasing energy consumption will be discussed in greater depth in the Insulation section. Insulation of contemporary windows with enhanced thermal features will dive deep into the role that cutting-edge window technology plays in fostering reduced energy consumption.

2.6.1.1 Lighting System

Lighting is among the biggest energy consumers in a building more so when artificial lighting is used all day in a building, that building will be using a large amount of energy. Some modern buildings have adopted the new glazed window as a way of providing the house with the proper insulation while at the same time providing sunlight for the building. However, they might lack open spaces in the building which makes them lose access to direct sunlight into these zones. Natural lighting is crucial for the end users of a building. The amount of natural lighting a window provides to the building is computed to show the amount of the light that can get into the building through the window with no obstructions (Ma et al., 2012). Hashemi (2014) holds that light shelves could be retrofitted to windows to have the daylight reflected into the building while at the same time minimizing the intensity opposite to the window. Also, sun pipes and rooflights could be installed to in corridors and interior rooms located at the top floor.

Natural light is important for a building's thermal performance which generally determines the user's thermal comfort (Oliveira et al., 2015). In a similar approach, automated or smart lighting could be added during retrofitting. In this type of artificial lighting, the control system is programmed in a way which it will ensure that daylight is maximized and the use of electricity in the building minimized. The control system generally provides the programmer with the ability to regulate the output of the lighting

device based on several factors. Including the availability of daylighting, occupancy level, the astronomical time, chronological time, and alarm conditions.

2.6.1.2 Occupant's Behavior

Humans continuously generate heat energy that is released into the environment. For an occupant to say that they are comfortable in a room, there must be a form of thermal neutrality where the conditions can be described as not being too hot or too cold. Nationality, sex, and age are some of the factors that can affect the level of thermal neutrality, and researchers have not found any differences between the demographics. According to previous research, results on thermal comfort has been consistent across these demographics. People will only complain about their thermal comfort when they have moved from their comfort zone into a stressful condition.

One division of the six factors affecting a person's thermal comfort is the environmental factors comprising of air temperature, relative humidity, air velocity, and mean radiant temperature. Air temperature refers to the average temperature of the ambience and it directly affects heat loss through respiration and convection. The temperature of the body stands at an average of 35°C, with the heat loss from the body getting directly affected with the difference between air temperature and skin temperature. Additionally, majority of the surfaces that people come into engage with are relatively stable at room temperature. Therefore, the loss of heat from the body into the surfaces through conduction depends on and is proportional to the ambience air temperature. According to Watt (2012), 50% of the body heat for a person living a sedentary lifestyle is lost through convection while 25% of the heat is lost through conduction. Holding all other factors constant, an average person would say that the air temperature is comfortable at 24°C.

Then, relative humidity is another environmental factor that has a huge role to play in a person's heat loss. Besides convection and conduction, heat from the body is also lost through respiration and perspiration. Humidity in the atmosphere can greatly vary without causing any significant discomfort in a person. However, there are limits to which a person can accommodate because too much of humidity could facilitate the growth and spread of bacteria and viruses while too less of it could lead to static electricity and respiratory issues. Toftum and Fanger (1999) argue that the relative humidity of a unit should be maintained at 25-60%, a range which is considered optimal such that every person can be comfortable with it. With the rest of the factors held constant, then a 50% humidity could be considered just perfect.

Another factor is the velocity of the air. The velocity of the air determines the level of cooling effect it is going to have in a room because it increases the convective heat losses. Nonetheless, there are limits to which a human can accommodate the speed and velocity of the air travelling through the openings. Air velocity going well above 150 feet per minute (fpm) can move papers from the desks and might make a person start feeling drafty. Such a velocity will lead to dehydration if a person experiences it for more than 8 hours consecutively (Wyndham et al., 1952). Movements less than 40 fpm cannot be felt; other factors being held constant, a human will be able to withstand a 50 fpm air velocity.

The next environmental factor that determines heat loss from the body is the mean radiant temperature. Prakash (2000) hold that everybody with temperatures more than -459°F which is absolute zero tend to lose heat energy through radiation. This means that human bodies are prone to heat losses because their body temperatures are way above the absolute zero. All those surfaces that surround the human body also radiate

because they have temperatures above the absolute zero. Technically, there is heat exchanges between the surfaces surrounding human body and the human body through radiation. If the surrounding surfaces are warmer than the human body, heat will travel from the surrounding surfaces to the human body while the reverse direction will be observed if the human body is colder than the surrounding surfaces. When a person is seated, then about 25% of the heat loss from the body is lost through radiation to the surrounding cold surfaces. The amount of heat lost through radiation might be immensely changed if there are non-standard environmental conditions such as a cold door surface. In a normal setting the temperature of the surfaces is considered to be similar to that of the air temperature.

The next category of factors are adaptive variables including activity and clothing levels. The level of activity is measured in metabolic equivalents, or mets. One met is the amount of energy that is consumed when a person is seated. Therefore, the mets will increase when a person is carrying out a physical activity to show its intensity; for instance, a running person could be using 8-9 mets while reading could use 1.3 mets (Dong et al., 2004). The next adaptive variable is clothing level which change much affecting the comfort level of a person. Clo is the unit used in measuring the thermal comfort of clothes by assessing its heating or cooling enhancing effects.

2.6.1.3 HVAC Systems

Retrofitting refers to the process of upgrading existing buildings to improve energy efficiency. According to Song et al. (2020), retrofitting can be a cost-effective way to improve energy efficiency, particularly in older buildings that were not designed with energy efficiency in mind. Upgrading insulation, replacing windows, upgrading HVAC systems, and installing energy-efficient lighting are examples of retrofitting.

Energy management involves using technology and data analysis to optimize building energy use. According to Zhang et al. (2020), energy monitoring systems, building automation systems, and smart controls for lighting and HVAC are examples of energy management. Energy management systems can monitor energy consumption, identify areas of inefficiency, and adjust building systems in real-time to minimize energy use.

HVAC systems play a pivotal role in optimizing energy efficiency within high-rise buildings, while simultaneously ensuring optimal thermal comfort and upholding the quality of indoor air. In order to achieve optimal efficiency, the utilization of advanced technologies such as variable refrigerant flow (VRF) systems and energy recovery ventilators (ERV) is imperative. A study by (Simpeh et al., 2021) found that smart HVAC control strategies in high-rise buildings can significantly conserve energy and reduce carbon emissions. This approach has the potential to make a significant contribution towards sustainable urban development and address the challenges posed by global climate change.

2.6.2 Passive Measures

Passive systems refer to design strategies that use the building's form, orientation, and materials to reduce energy consumption. Passive systems, as discussed by Alshawi et al. (2018) encompass ventilation, daylighting and insulation. Natural ventilation allows for the circulation of air, within a building maintaining indoor temperatures without relying on mechanical systems. Daylighting utilizes windows and skylights to light and decrease dependence on artificial lighting. High performance insulation materials help retain heat during winter and keep buildings cool in summer reducing the necessity for heating and cooling systems.

2.6.2.1 Building Materials

Construction companies have the opportunity to make a high-rise building as energy efficient as possible because they build them from scratch unlike other buildings which are bought when they are already complete. This way, the company and the client can agree on the right material selection to make it more energy efficient because if any material was to be selected then the building would use much more energy and that would undermine the global efforts of reducing energy consumption. Materials are usually selected depending on the design that the client wants to have as well as the geographical location of the house because of the differences in climatic conditions. No matter the reason for selecting a particular type of material, the construction company ought to ensure that the materials are as energy efficient as possible. Materials affect the thermal performance of a building in that different materials absorb, reflect, or retain heat at different rates. For example, concrete absorbs more solar energy during the day than steel does and retains much of it at night. This means that a high-rise building with concrete beams would have a better thermal performance as compared to a building whose beam is made of steel. Steel, being a metal is a good conductor of heat, meaning that heat is absorbed, transferred, and lost at a faster rate on steel than on concrete or wood. Therefore, steel-made buildings are less energy efficient and would need more energy to cool during hot weather conditions and more energy to heat during cold weather conditions.

Nevertheless, much solar absorption would mean more heat in the rooms which might necessitate cooling during the day (Al-Obaidi et al., 2014). To ensure that considerable amount of solar heat is absorbed especially in high heat areas, light-colored and smooth materials. However, the color shade and texture spectrum, should be adjusted appropriately according to the needs of the geographical location of the high-rise

building. There is an array of materials that might be selected in the contemporary construction industry to have to help in the use of natural heat without necessitating the use of artificial thermal control mechanisms (Fernandes et al., 2019). The materials used should require little to no maintenance over an extended period. Besides, the materials should be sustainably harvested, be non-toxic, have minimal to no pollution, leave the health of the occupants less vulnerable to danger, and be easy to re-use and recycle (Mostafavi et al., 2021).

The ability of a material to absorb and transmit thermal energy determines its energy efficiency and thus that of the entire building. The measure of heat loss through the construction material is referred to as thermal transmittance or heat remittance which is among the ways of expressing a building's energy performance (Utama and Gheewala, 2009). The thermal transmittance value describes how well a material conducts heat from one part to another by calculating the amount of heat the element allows to pass through within a given time. Most of the building codes use the U-value as a standard to specify the minimum energy efficiency of a high-rise building. The U-value is measured differently for exterior components such as walls and openings such as ventilation, doors, and windows. However, the thermal transmittance can as well be used in rating the energy efficiency of the combined materials in a building section or component. This is usually applicable in hybrid systems which are common in high-rise buildings. The lower the thermal transmittance, the better the energy efficiency of the building or section under assessment (Fernandes et al., 2019). Some codes set minimum requirements for windows, doors, walls and skylights because these components can gain heat and increase the amount of energy consumed while cooling the building.

Generally, the endeavor to have energy-efficient high-rise buildings means getting into a mission for a tight envelop. A tight envelop means that it can keep the structure out of rain and wind and other extreme weather conditions that apply horizontal and vertical load on the building. High-energy efficiency is achieved if the designer can use a tight envelop simultaneously with some form of recyclable and renewable materials (Alesina and Lupton, 2010). However, many designers and construction companies in general avoid using energy-efficient construction materials because of the high costs which in turn increases the cost of building the product. However, Gutfleisch et al. (2011), like other energy conservation researchers and experts, argue that while the initial costs of energy-efficient construction materials could possibly be higher than the rest of the materials, it saves costs in the long-term because of the low costs of cooling and heating. Therefore, much of the initial costs are recovered over time.

2.6.2.2 Building Envelope Insulation

Insulation is a crucial aspect of passive energy efficiency in high-rise buildings. It aims to reduce heat transfer through the building envelope, primarily through the walls, which form the largest proportion of the structure (Hu, L et al., 2017). The choice of insulation material and method of application depends on the specific building and its location. The insulation material traps air pockets to slow down thermal energy transfer into or out of the building, and the efficiency of this process is measured using the R-value.

However, even with effective insulation, thermal bridging can occur when heat passes through a more conductive material in the building envelope, such as steel, wood, or concrete. This can significantly reduce the building's energy performance, leading to unwanted heat gain or loss (Real et al., 2016). Airtight building envelopes and high performance insulation can mitigate thermal bridging in high-rise buildings.

(Real et al., 2016) mentions that in high-rise buildings, the energy efficiency can be achieved through a combination of passive and active systems, with effective insulation and mitigation of thermal bridging being essential components of passive energy efficiency. By adopting such strategies, high-rise buildings can improve their energy efficiency and reduce their environmental impact.

2.6.2.3 Building Opening

In the conventional construction industries, windows had the lowest energy efficiency link in a building envelop brought about by the single-gazed windows. Single-pane openings with clear glasses dominated the traditional construction industry, providing a poor thermal feature. They used to allow the highest transfer of heat energy, either by having the building gain or lose heat depending on the climatic conditions of the region and permitted optimal daylight transmission into the building (Nundy and Ghosh, 2020). However, technological advancement has seen the single-gazed windows get extinct especially in high-rise buildings. A standard used for high-rise buildings in the contemporary architecture is a double-gazed window with insulation between the panes. These new windows prevent heat gain and loss which maintains the internal temperature of the building relatively stable. Such windows have U-values between 0.30 and 0.60 depending on how well the window insulates (Cuce and Riffat, 2015).

In most of the windows, the most important decision on energy efficiency is the glazing selection. Considering various factors such as building design, climate, and window orientation, a construction company may want to choose various forms of glazing for different windows throughout the building. According to D'Agostino and Parker (2018), virtually all the new energy-efficient buildings are using double or triple unit. One of the glasses used is the insulated ones which have two or more glass panes. An

insulation airspace is left between the two panes by having them hermetically sealed and spaced apart. This means that the pane will have a lower U-value and thus lowers the Solar Heat Gain Coefficient (SHGC). The openings could also be fitted with low emissivity (low e) coatings which is meant to regulate the heat transfer within the glazing. Abundiz-Cisneros et al. (2020) assert that windows with low-e coatings tend to be a little bit more costly than the regular windows but tend to reduce energy loss to a greater extent. Depending on the location of the building, there are different designs have been made to “allow for high solar gain, moderate solar gain, or low solar gain, and they can also be tuned to control the amount of visible daylight transmitted” (Tuchinda et al., 2006). Finally, there are spectrally selective coatings mostly in the areas where cooling loads dominate to provide daylight and transmit little sun's non-visible infrared radiation.

2.6.2.4 Curtain Walls

Curtain walls refer to thin portions of building envelopes with independent frame assemblies which has thin stones, metal panels, or glass as in-fills. The walls are designed not to support any loads, vertical or horizontal, but for energy efficiency purposes (Al-Jubori, 2018). However, since they are found to the exterior side of the wall, they are subject to gravity and wind loads. Nonetheless, besides the aesthetic roles which are seemingly the primary role, they allow light to enter into the interior space and also acts as a weather barrier against water and air. This way, they help a lot in controlling the energy value of a building.

By considering the material the engineer used for the construction process, then it is possible to save a huge amount of energy because installing curtain walls helps in reducing the cooling and heating loads on the structure. Through the use of glazing such as glass the temperatures on the inside of the building can remain efficiently

controlled by the envelop (Somasundaram et al., 2020). Besides, the glass curtain walls permit the passage of more natural light into the building which minimizes the need for artificial lighting during the day. When enough daylight can penetrate through a building's openings, then there is no need to light the building naturally depending on how the wall is placed (Kim, 2011). The engineer, architect, and the builder must ensure that a curtain wall is well-built to minimize the leakage of air into the building by having it properly sealed. In this manner, a building's thermal performance is generally enhanced by having controlled cool drafts. Nonetheless, there is no interior air beside the curtain walls of buildings, and this makes them vulnerable to rapid temperature changes. Therefore, there should be a careful selection of insulation to have condensation highly reduced. Extreme thermal loads in the building which are subjected by the glazing system are usually handled through a supply of high amount of cool and warm air into the perimeter area, where the cooling and heating loads are occurring.

2.7 Impact of Utilization of Energy Efficiency Measures in High-Rise Buildings

The procedures of designing and producing an assembly are included in the product phase of a building project. Inclusion of energy efficiency measures through the product stage of the life cycle of a building may have a significant influence on the end product's energy efficiency. (Kaygusuz, 2021) states that sustainable design principles such as solar design, excellent insulating properties, and the adoption of energy-saving materials can reduce energy consumption. Utilizing innovative manufacturing techniques, such as off-site manufacturing and modular construction, can simultaneously increase energy efficiency and decrease waste. In order to

accomplish optimum energy efficiency at this time, it is imperative that designers, engineers, and manufacturers collaborate.

During the construction process, it is possible to implement energy efficiency measures that, if successful, can result in substantial energy and environmental impact savings. According to Zhang et al. 2021, the use of eco-friendly building materials, such as recycled or locally sourced materials, reduces the environmental impact caused by the extraction and transportation of natural materials. This phase's energy efficiency can be improved further by optimizing the site administration methods currently in use. These activities include effective logistics, waste management, and the recycling of construction refuse. According to research conducted by Zhang et al. in 2021, modern construction techniques such as prefabrication and modular construction improve energy performance by reducing the amount of time spent building, minimizing disruption on the construction site, and maximizing the use of available resources.

The majority of a building's total energy consumption occurs during its operational existence, which corresponds to its usage phase. It is crucial to implement energy efficiency measures at this stage in order to minimize the amount of energy required and maximize the amount of energy used. (Iwayemi et al., 2011) emphasize the importance of intelligent energy management systems, occupant behavior awareness programs, and energy monitoring systems for achieving energy-efficient operations. These techniques permit the optimization of energy-consuming components such as heating, ventilation, and air conditioning (HVAC), lighting, and other components, resulting in substantial energy savings and improved occupant comfort.

There are opportunities to implement energy efficiency measures during the end-of-life period through responsible demolition and waste management techniques. (Zabalza Bribián et al., 2011) underline the need of considering the environmental consequences of building materials as well as their energy efficiency throughout the demolition process. According to research conducted by (Ma et al., 2020), deconstruction strategies that promote material recovery and recycling may help reduce the quantity of embodied energy associated with new construction projects. Effective waste management contributes to the reduction of an organization's ecological footprint.

2.8 Challenges in Adopting Energy Efficiency Measures Worldwide

Adoption of building energy efficiency measures is crucial for combating climate change and achieving sustainable development objectives. However, a number of obstacles impede the global implementation of these measures.

A lack of awareness and knowledge among stakeholders is one of the most significant obstacles to adopting building energy efficiency measures globally. Numerous building owners, developers, and occupants are oblivious of energy efficiency's prospective benefits and cost reductions. This dearth of awareness hinders the adoption of energy-efficient practices and technologies (Oladokun et al., 2020). Educating stakeholders on the benefits and financial incentives of energy efficiency is essential for overcoming this obstacle and promoting wider adoption.

Another barrier to the adoption of building energy efficiency measures is monetary. High initial costs and lengthy repayment periods discourage building owners from investing in energy-efficient retrofits and technologies. Liu et al. (2010) note that

limited access to affordable financing options exacerbates the financial challenge. To surmount these financial barriers and encourage building owners to invest in energy efficiency, governments, financial institutions, and international organizations must develop and implement innovative financing mechanisms, such as green bonds or energy efficiency funds.

In addition, regulatory and policy frameworks have a significant impact on the global adoption of building energy efficiency measures. Sims et al. (2018) report that inconsistent regulations, ineffective enforcement mechanisms, and a lack of stringent building energy codes impede the widespread implementation of energy efficiency measures. Inadequate policy support and hazy objectives create uncertainty among stakeholders, impeding investment and dedication to energy efficiency improvements. To encourage widespread adoption of energy efficiency measures, governments and policymakers must establish robust regulatory frameworks, establish ambitious energy efficiency targets, and provide unambiguous incentives and penalties.

2.9 Challenges in Adopting Energy Efficiency Measures (Iraq Case)

In the Middle East, including Iraq, specific obstacles further confound the adoption of energy-efficient building measures. Iraq confronts a number of unique challenges, including lack of awareness, limited access to technology, inadequate regulatory framework, and insufficient financing alongside with some other minor challenges as political instability, and limited resources. Continual conflicts and geopolitical issues have shifted focus and resources away from energy efficiency initiatives (Ali, 2020). Moreover, an unreliable and expensive energy supply prevents the adoption of energy-efficient technologies.

The economic difficulties in Iraq, including a feeble financial sector and limited access to capital, pose significant obstacles to the investment in energy-efficient building measures. The high initial costs associated with retrofitting existing buildings or implementing energy-efficient technologies discourage building owners from pursuing these projects (Rzaev & Al-Khafaji, 2021). Due to competing demands for scarce resources, stakeholders may not prioritize energy-saving measures due to a lack of public awareness and comprehension of energy efficiency.

In addition, the lack of comprehensive building energy codes and standards in Iraq hinders the implementation of energy-saving measures. The lack of clear regulations and guidelines pertaining to the planning and buildup of energy-efficient buildings poses a barrier to the integration of energy-saving features (Ali, 2020). A scarcity of skilled workers and educational opportunities in energy efficiency further impedes the nation's adoption of energy efficiency measures.

2.10 Construction Life Cycle Definitions

The construction life cycle comprises four stages: design (product phase), construction, operational (use phase), and end of life. It encompasses the entire process of planning, building, utilizing, and eventually decommissioning a construction project as shown in **Figure 1**.

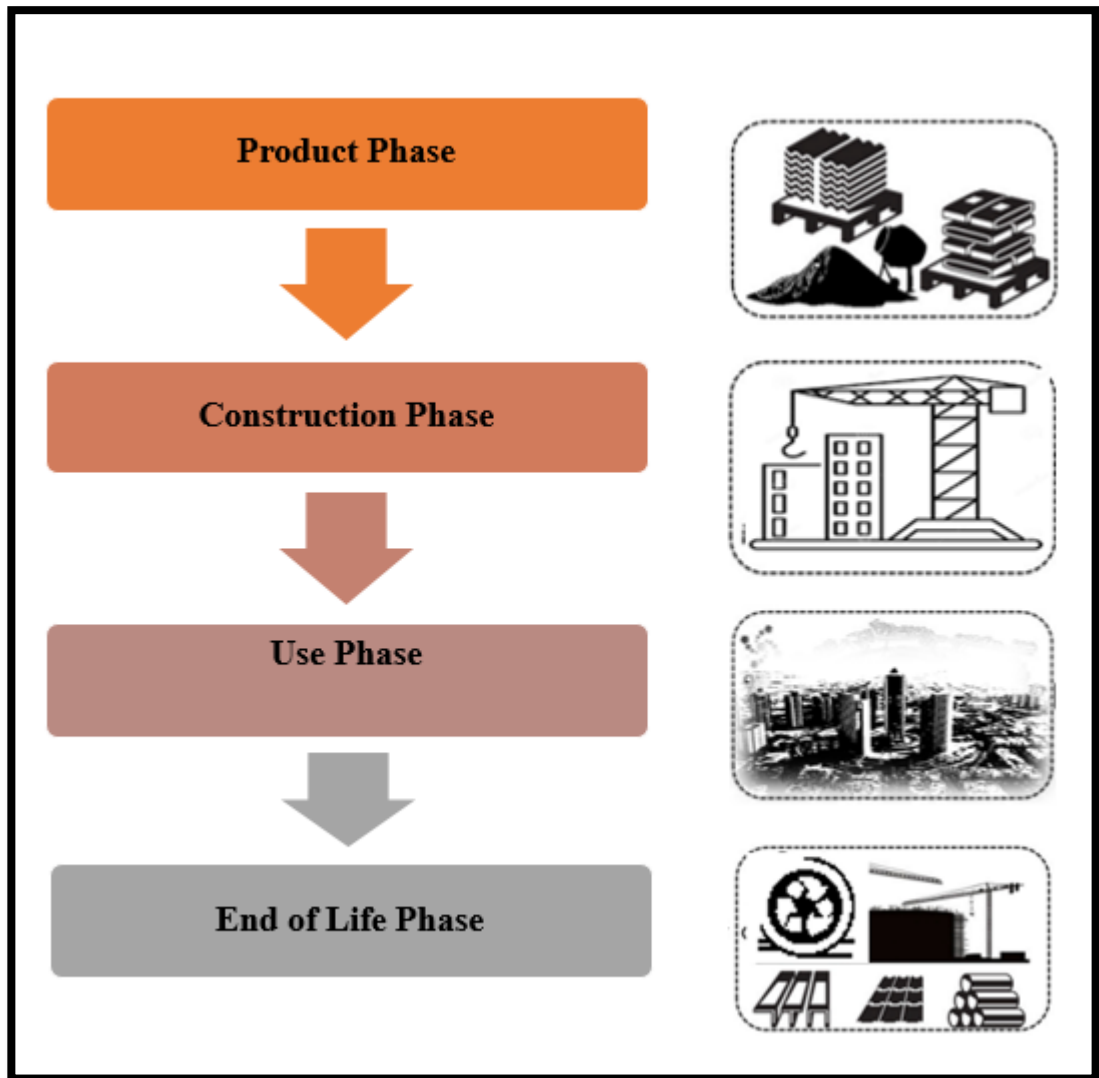


Figure 1: Construction Life Cycle Stages.

2.10.1 Product Stage

The construction life cycle incorporates multiple stages, ranging from the initial product creation to managing of a built environment's end-of-life. It can be grouped into four separate stages: the product phase, the construction phase, the use phase, and the end-of-life phase. Efficient project management, sustainability variables, and optimizing resources all require a comprehensive understanding of each phase (Imad Shakir et al., 2021).

2.10.2 Construction Stage

The construction project is conceptualized and designed during the product phase. During the product stage, the project's goals, demands, and specifications for design are determined. Architects and designers develop comprehensive design paperwork, drawings for engineering, and specifications in collaboration with stakeholders. To optimize energy performance and decrease environmental impact, environmentally friendly design principles such as maximizing the building envelope, choosing efficient resources, and promoting renewable energy systems can be evaluated at this stage (Crawley et al., 2020).

The construction phase of an undertaking entails its physical realization. It comprises site preparation, resource procurement, and construction. The construction process is coordinated by the project managers and construction teams to ensure that the design purpose is achieved accurately and efficiently. This phase requires efficient project management, resource allocation and quality control to ensure the project is completed on time and within budget limitations.

2.10.3 Use Stage

After construction is complete and the facility has been occupied, the use phase commences. During this phase, the energy efficacy and efficiency of the building are crucial. The management and occupants of a building play an important part in maximizing energy consumption through the application of appropriate operation and maintenance procedures. Monitoring energy consumption, instituting energy management systems, and encouraging occupant awareness and behavior modification can all contribute to energy efficiency during the use phase (Fabi et al., 2019).

2.10.4 End of Life Stage

The end-of-life phase is the concluding stage in the construction life cycle, when a structure reaches the conclusion of its functional lifecycle. The building is decommissioned, demolished, or repurposed during this phase. To reduce waste and increase material recovery, sustainable practices such as deconstruction and recycling can be utilized (Rauhala et al., 2020). Consideration of the environmental impact of the end-of-life phase is essential for the promotion of circular economy principles and the reduction of resource depletion.

2.11 Key Performance Indicators (KPI)s Definition

Energy Supply (Renewable/Non-Renewable %): The relative balance of energy supply, sourced from either renewable or non-renewable sources. (Deng et al., 2023)

Energy Saving Potentials: The potential for energy conservation achievable through diverse efficiency measures, quantified in Gigajoules (GJ), Megawatt-hours (MWh), kilowatt-hours (kWh), or Percentage (%) (Chedwal et al., 2015).

Energy Consumption: The aggregate energy utilization within the building or site, measured over a specified period, often quantified in Gigajoules (GJ), Megawatt-hours (MWh), or kilowatt-hours (kWh) (Guo et al., 2023).

Emissions: The cumulative amount of greenhouse gases or other pollutants released from the building or related activities, typically gauged in kilograms (kg) (Guo et al., 2023).

Water: The total water consumption or utilization within the building or site during a specified period, usually measured in cubic meters (m³). (Liu et al., 2022)

Water Pollution: The degradation of water quality due to building activities or other influencing factors (Chaturvedi, 2015).

Water Supply (Local, Rainwater m³ or %): The proportion of water supply derived locally or from rainwater harvesting, frequently measured in cubic meters (m³) or percentage (%) (Chaturvedi, 2015).

Water Saving Potentials: The potential water conservation achievable through diverse efficiency measures, quantified in cubic meters (m³) or percentage (%) (Chaturvedi, 2015).

Air Quality (ppm): The concentration of air pollutants gauged in parts per million (ppm) (Mannan & Al-Ghamdi, 2021).

Daylight: The amount of natural sunlight available or integrated into the building design (Mannan & Al-Ghamdi, 2021).

Thermal Comfort (°C): The desired or comfortable temperature range for building occupants, typically measured in degrees Celsius (°C) (Nicol & Humphreys, 2002).

2.12 Gap Analysis

Energy efficiency, in buildings is a priority for protecting the environment and promoting development. Assessing building energy efficiency through Key Performance Indicators (KPIs) is valuable. However existing research falls short in addressing the limited use of KPIs for stages of building projects in Iraqs construction industry. Given Iraqs challenges it is crucial to have an adaptable framework that incorporates KPIs and considers the lifecycle phases of buildings. This study presents

an approach that combines KPIs with Iraq's building process to bridge this information gap. The ultimate goal is to promote energy building practices throughout the lifecycle. The construction industry plays a role in Iraq's growth, but it faces challenges related to climate conditions, resource limitations and evolving regulations that hinder energy efficiency efforts. Despite the industry's focus on construction there is research on specific KPIs, for different construction phases, which limits the adoption of energy efficient methods. To address these challenges effectively it is essential to understand energy efficiency requirements at each stage of development and create targeted plans accordingly.

Iraq currently lacks a framework that aligns KPIs with lifecycle phases, which makes measuring and monitoring energy efficiency challenging.

This approach is crucial, for evaluating the effectiveness of construction at every stage identifying areas that need improvement and comparing performance to industry standards. Therefore the lack of knowledge in this area hampers the industry's ability to make decisions based on evidence and implement energy efficient practices.

This study fills a gap in existing literature by presenting a perspective for the Iraq Construction Industry. Starting from planning and design all the way to operation and maintenance the proposed framework would incorporate Key Performance Indicators (KPIs) for each phase. Moreover it would take into consideration energy efficiency in building projects while accommodating their changing nature. The framework will address challenges throughout every step of construction.

Additionally this research sheds light on energy efficient building techniques and resource allocation specific to Iraq. The suggested framework equips architects, engineers, contractors and policymakers with tools and information needed to make decisions and effectively implement energy saving measures during construction.

Closing the information gap will also facilitate assessing the long term impacts of energy construction strategies. This methodology enables evaluation and enhancement of energy efficiency measures, over a buildings lifespan ensuring that structures remain environmentally responsible and resource efficient.

Furthermore this work can contribute insights to inform building policies and future research endeavors.

In order to promote energy efficiency and sustainability, in Iraq it is important to establish indicators within the country's context. By doing this can influence standards encourage the adoption of energy efficient designs and construction practices and contribute to Iraq's overall sustainability goals.

To address a gap in literature pertaining to Key Performance Indicators (KPIs) for different stages of high-rise building construction in Iraq's Construction Industry it becomes crucial to develop a flexible framework. This framework will help bridge this knowledge gap and create an environment that promotes energy building practices throughout Iraq.

Aligning KPIs with stages of construction allows stakeholders to make informed decisions that enhance energy efficiency and promote sustainability in the built

environment. By addressing this knowledge gap, it could help the Iraq Construction Industry develop strategies for resource management and establish itself as an advocate for energy practices in line, with global sustainable trends.

Chapter 3

METHODOLOGY

3.1 Introduction

The chapter presents the method that was employed to complete the study. In this light, the chapter will describe the study areas selected and justification underpinning the selection of the particular study area. A thorough explanation of the research design, data collection procedure, the including and exclusion criteria, the quality assessment of the entire process, and how the collected data was analyzed will be presented in the current chapter. The researcher also provides an explanation of the selection of the articles and validation offered. The chapter will be useful because it will help the future researchers in understanding the gap in methodology from the current study and provide them with a foundation to their future studies.

3.2 Research Design

The study's success hinges on the careful selection of its research design, which provided the necessary structure for data collection and analysis methods tailored to the research objectives (Astalin, 2013). To ensure a thorough evaluation of high-rise buildings' energy performance, an unconventional qualitative research design was employed. Various sources, including articles and relevant websites were tapped into through a systematic analysis approach. By rigorously collecting, evaluating, and interpreting data, the study aims to obtain a holistic comprehension of tall structures' energy efficiency. The qualitative approach offers an avenue for exploring subjective factors and underlying influences on energy performance, as well as facilitating an in-

depth examination of the contextual elements that shape energy consumption patterns in high-rise buildings. The research design, through its utilization of qualitative methods, effectively tackled the research questions and contribute to a well-rounded understanding of energy efficiency in high-rise buildings.

3.3 Methodology Framework

This thesis presents an approach, to developing a framework that effectively utilizes Key Performance Indicators (KPIs) throughout different stages of the construction life cycle. The framework comprises seven steps as shown in **Figure 2**.

Literature Review: in this paper the researcher extensively examines literature and relevant research on performance indicators (KPIs) the various phases of the construction life cycle and performance evaluation. This initial stage establishes the foundation for our research. Identifies any existing gaps in the field.

Gap Analysis: Building upon our review of literature this phase involves a meticulous assessment of identified gaps to understand the limitations of current Key Performance Indicator (KPI) frameworks and identify areas that require improvement.

Data Collection: To gather a diverse dataset this study combines primary and secondary data collection methods from sources such, as construction projects, industry experts and case studies.

Inclusion and Exclusion Criteria: The process of screening data involves applying established criteria to include or exclude specific data. Our analysis incorporates data that meets these criteria while excluding insufficient data.

Thematic Analysis: the researcher conducted a six stage approach to analyze and interpret the collected data. The process involves familiarizing with the data, creating codes, searching for themes, extensively refining and reviewing these themes, giving those names, and finally summarizing the findings into a cohesive report.

The results related to Key Performance Indicators (KPIs) are thoroughly discussed in relation, to stages of the construction life cycle. This analysis aims to highlight the significance of these KPIs and explore their applications.

Based on the findings, the researcher have developed a flexible framework that offers insights for effectively utilizing KPIs throughout various stages of the construction life cycle. This framework can greatly contribute to decision making, performance assessment and overall project success.

By adopting an approach this thesis aims to make contributions, towards improving and standardizing performance evaluation practices within the high-rise construction industry.

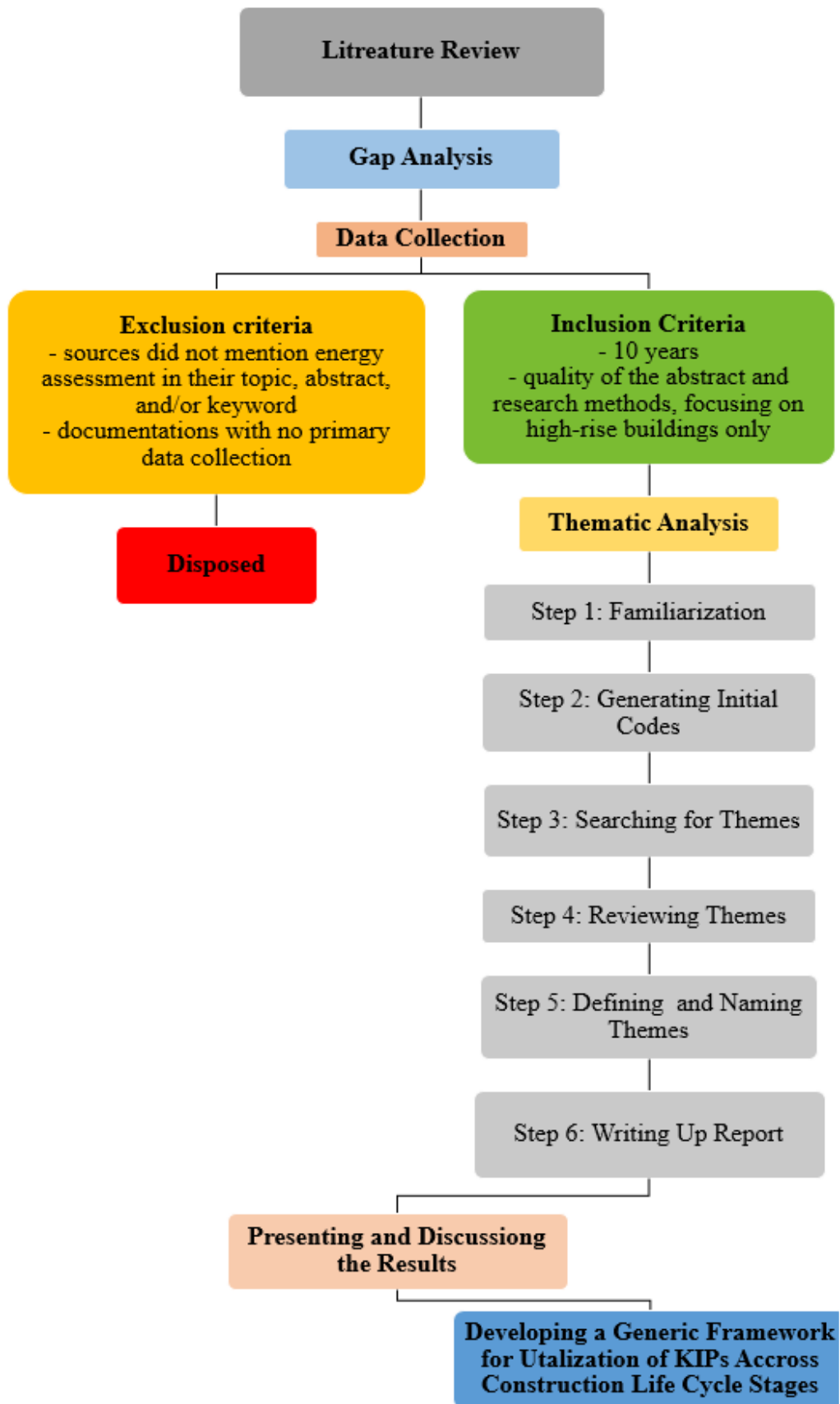


Figure 2: Methodology Framework Design.

3.4 Data Collection

The aim of collecting data was to end up with a collection of articles to be used in the final stages of the study. To do this, six databases were searched for the articles using the pre-determined search terms and phrases; the databases are Research Gate, Google Scholar, JSTOR, Wiley Online, Taylor & Francis, and Elsevier. The keywords selected were those relating to the building energy performance assessment in high-rise buildings. The researcher used filters to obtain only those articles published in the past 10 years and published in English language. However, exceptions were given to landmark articles published before 2012. Before considering an article fit for use, the reference list found in a particular database was first analyzed to ensure credibility of the sources selected. The research was carried out towards the end of 2022. The search terms used in the databases include efficient measurement of building energy, building energy performance measurement, building energy efficiency evaluation, and building energy assessment. The search process for the articles relating to building energy assessment involved three major steps: the first one was scanning the titles, keywords, and abstracts of the articles obtained with the related search terms. The researcher scaled down the search by concentrating on the articles published within 2012-2022 because currency is a major concern in systematic reviews; secondly, the researcher briefly reviewed the abstract of the papers to discard those that are not closely related to the topic in question; and third one was to make a list of the articles obtained with information closely related to energy efficiency measurement to analyze them further.

3.5 Inclusion and Exclusion Criteria

Initially, the results of the search produced 3,000 results from the six databases. This was a huge collection of articles and could consume a lot of time to analyze. Besides, the articles defy the credibility check of currency since they were published more than

10 years ago and chances are that they have a lot of junk information or outdated data. As such, inclusion/ exclusion criteria were important to help in selecting the best articles to use and ones with the ability to analyze within the shortest time possible. Only those articles that remained after the screening process were to be used in the study. Those articles that did not use high-rise buildings for the research or did not focus on energy assessment techniques were excluded from the study.

The first feature that was a must-have for the article to be included in the study was the quality of the abstract and research methods. The abstract tells the reader what the study is all about. Therefore, its transparency was a major consideration because it was the one the researcher scanned before reading the entire article. It would be impossible to read the entire collecting before filtering. Besides, the methods selected mattered because methods affect the credibility of findings and some methods could be irrelevant in some instances. The second inclusion criterion was currency, requiring that the articles be published within the past 10 years, beyond which the information would be considered irrelevant. However, there were a few exceptions of landmark articles that made a difference in the energy assessment of high-rise buildings that could be included regardless of the publication date. The third inclusion criterion was that the article must be focusing on high-rise buildings only. There were many articles covering energy efficiency of low-rise buildings which are not part of the current study. Additionally, the articles were supposed to specifically talk about measurement of energy efficiency; many articles were only talking about energy efficiency without explaining how it could be measured or comparing different methods of assessment. Besides, the article had to be published in English languages only, unless the article was in Turkish and Arabic, and a landmark article that changed the history of

engineering in general. Finally the papers had to be peer-reviewed to enhance credibility.

After having 3,000 articles, there were various criteria used to exclude some from the list. First, all articles that did not mention energy assessment in their topic, abstract, and/or keywords sections were excluded from the list. Those addressing energy efficiency or consumption in general were excluded from the study. Besides, concept papers and other documentations with no primary data collection procedure were excluded from the study. This included meta-analyses and systematic literature reviews because they did not involve having the researcher collecting data first hand from the respondents.

3.6 Quality Assessment

To ensure that the current study meets some set standards, the researcher screened it using the criteria from Centre for Reviews and Disseminations (CDR). There are various questions that the researcher needs to ask themselves to ensure that the review is best fit for the general audience. First, the author has to adequately include the inclusion and exclusion criteria. Stating the criteria helps in increasing the possibility of having reproducible and reliable results because the subjects are included in the study following a particular pre-defined characteristic rather than doing it randomly. The second criteria is to have the researcher covering all the relevant researches which are related to the topic. In the current study, all the articles selected were related to energy assessment in high-rise buildings and the same was included in the inclusion/exclusion criteria with no exceptions allowed whatsoever. The third one is to make sure to describe the quality and validity of the study and describe all the

fundamental data in the study. These two are to be include in the later sections of the study.

3.7 Data Analysis

The collected data was analyzed using thematic analysis, adapted for the purpose of secondary data synthesis of thematic analysis and offers the established techniques and methods for identifying and developing the analytical themes in primary research data. The method was well-suited for the current study because it fits well with the objective of aggregating the extant evidence and identifying patterns in the data. Besides, while thematic analysis is mostly associated with the analysis of qualitative data, when it comes to systematic reviews, it could be used in analyzing the outcomes of a quantitative research, more so in the cases where the variables and measurements are heterogeneous. Lastly, thematic synthesis process provides accessibility of outcomes and good transparency.

The thematic analysis was conducted in six stages which were could be applied for both qualitative and quantitative studies.

1. Familiarization: The Familiarization stage is the first phase of the thematic analysis process, during which the researcher engages in an in-depth examination of the extensive body of scholarly literature. The present phase is distinguished by a profound involvement with the abstracts, conclusions, and summaries of papers pertaining to energy efficiency and Key Performance Indicators (KPIs) in the specific domain of high-rise building development in Iraq. Nevertheless, this procedure goes beyond a simple survey of literature; it embodies a dynamic exchange that influences the

succeeding analytical stages, grounding the researcher's comprehension inside the established academic conversation.

The key focus of this stage is to comprehend the fundamental nature of the study area. The endeavor at hand involves more than a cursory interaction with language; rather, it is a diligent attempt to comprehend the fundamental forces, patterns, and deficiencies that shape the dialogue around energy efficiency and sustainability evaluation in tall structures. The process of immersive exploration necessitates the practice of thorough note-taking, which afterwards transforms into a guiding compass for the researcher inside the complex and complicated landscape. The aforementioned comments undergo a transformation, assuming the role of signs that direct the researcher towards fundamental elements, recurring themes, and possible deficiencies within the existing body of literature.

The process of becoming familiar, with a range of ideas, approaches and discoveries is essential. The researcher is engaged in a process of not just collecting data, but also comprehending the many intricacies included in the academic literature. During this procedure, the researcher not only familiarizes themselves with the current trends but also acquires understanding of the developing viewpoints and changes within the discipline. The process of familiarization entails embarking on a journey of exploration, whereby the researcher fully engages with the academic discourse in order to traverse its many pathway (Braun & Clarke, 2006).

The current phase has a significant influence on the upcoming analytical procedure. The thorough involvement with the existing body of literature guarantees that the future examination of themes is firmly based on a full comprehension of the study

field. This methodology allows the researcher to discern synergistic relationships, paradoxes, and gaps that may not be readily apparent upon first perusal. The first phase of familiarization might be likened to the process of establishing the groundwork for a structure, as it guarantees that the future analysis is based on a comprehensive comprehension of the topic at hand.

Additionally, this phase functions as a wellspring of ideas. The researcher gets valuable information not just about current study but also regarding new areas for further investigation. The gaps and unresolved issues that are found in this phase serve as the trigger for the succeeding phases of the theme analysis. The researcher is directed by these tools towards topics and inquiries that have significance and pertinence within the framework of evaluating energy efficiency in high-rise structures.

The Familiarization stage may be characterized as an active and ongoing involvement with the academic conversation. The act of engaging in research shifts the researcher's role from that of an external observer to an informed participant inside the ongoing discourse. By engaging in a rigorous practice of recording detailed observations, the researcher develops a heightened sensitivity to the dynamic nature of concepts, patterns, and deficiencies present in the existing body of scholarly work. The first phase of involvement establishes the foundation for the succeeding phases of theme analysis, guaranteeing that the examination of energy efficiency and key performance indicators (KPIs) in the construction of high-rise buildings is firmly rooted in a comprehensive comprehension of the topic.

2. Generating Initial Codes: Within the framework of the thesis, a comprehensive examination of 69 articles sourced from esteemed scholarly publications was undertaken, highlighting the pivotal role of the Generating Initial Codes phase in the process of theme analysis. This phase signifies a significant shift in the researcher's role, as they go from a passive reader to an engaged interpreter. During this step, the researcher organizes the textual material into a structured framework, which facilitates the emergence of profound insights and meaningful patterns.

The first step included a thorough selection and organization of 69 scholarly publications sourced from esteemed academic journals. These articles were chosen for their authoritative content pertaining to the domain of energy efficiency and sustainability evaluation in the context of constructing high-rise buildings. The establishment of this repository served as the foundational basis for the construction of the full theme analysis. The researcher used the papers as a foundation for extracting profound significance by manipulating the collective knowledge, insights, and intellectual contributions encapsulated inside them (Guest et al., 2012).

Upon thorough examination of the papers, the researcher meticulously analyzed their content, carefully selecting significant concepts, ideas, and observations that aligned with the overarching study objective. The technique of Generating Initial Codes was a distillation process, whereby the fundamental elements of each article were distilled into concise codes that captured the primary ideas, arguments, and insights offered.

Within the context of evaluating energy efficiency in the construction of high-rise buildings, several codes have been developed, such as "Insulation-UsagePhase-Effectiveness" and "KPI-EnergyUseIntensity." The assigned codes were not randomly

chosen designations; rather, they were deliberately formulated to represent distinct notions. For instance : the term "Insulation-UsagePhase-Effectiveness" effectively encompasses the concept of insulation's efficacy throughout various stages of building utilization, while "KPI-EnergyUseIntensity" simply captures the core substance of Key Performance Indicators pertaining to energy use intensity.

The process of code generation included more than basic categorization; it was an act of interpretation. The researcher was required to fully immerse oneself in the subject matter, actively interact with the concepts offered, and condense intricate tales into succinct codes. The aforementioned procedure facilitated the conversion of textual material into a well-organized framework that had the capacity to be methodically examined and comprehensively explored in later phases (Nowell et al., 2017).

The researcher used a systematic framework of codes, which functioned as a comprehensive toolset, enabling them to effectively identify and analyze themes and patterns. The codes served as a valuable tool for the researcher, providing guidance in navigating the complex landscape of information. Their purpose was to facilitate the acquisition of significant insights, which in turn would aid in addressing knowledge gaps and promoting advancements in energy efficiency within the realm of high-rise building construction.

The Generating Initial Codes step served as the means through which the extensive body of scholarly material was condensed into a systematic framework of codes. During this phase, the researcher actively interacted with the material, carefully transforming textual data into significant indicators. These codes would serve as the fundamental components upon which following theme investigations would be

developed, enabling the researcher to go deeper into the core of the study and uncover the underlying layers of understanding hidden within the academic discourse. The process of interpretation has started, establishing the foundation for the formation of recurring themes and patterns that will influence the narrative around energy efficiency in the construction of high-rise buildings (Morgan, 2022).

3. Searching for Themes: This phase signifies a shift from the analysis of individual articles to the skill of identifying patterns and the formation of themes. This phase marks the transition of the researcher from the analysis of discrete codes to the synthesis of interrelated concepts that shape the language around energy efficiency and sustainability evaluation in the context of high-rise building development.

The collection consists of 69 articles that have been meticulously chosen as foundational sources of information in the specific field of interest. These articles include a wide range of valuable ideas, arguments, and opinions. The approach of searching for themes included a fluid procedure of categorizing and re-categorizing the original codes that were created. The codes in question may be likened to individual pieces, awaiting arrangement into more comprehensive and cohesive patterns that would ultimately unveil the fundamental story of the study topic.

Upon thorough examination of the codes, patterns and interrelationships started to emerge. Codes with similar characteristics had a tendency to cluster together, indicating the presence of common ideas or repeating themes. These clusters represented emerging ideas that were yet to be discovered within the academic discourse. As an example, concepts such as "Energy-saving materials" and "Energy-efficient design" started to converge, indicating the creation of overarching themes

pertaining to architectural and material approaches aimed at enhancing energy efficiency.

The method of identifying themes was characterized by a lack of mechanization, instead relying on intuition and interpretation. The researcher's capacity to discern links and correlations extending beyond superficial codes was necessary. Every line of code functioned as a metaphorical thread, while the underlying concepts served as the interwoven threads that together formed a cohesive narrative structure. The responsibility of integrating these many strands into a cohesive and significant entity fell upon the researcher.

As the themes gradually emerged, they shed light on the underlying principles that extended across several pieces. Clusters of concepts such as "Energy-saving materials," "Energy-efficient design," "Energy usage," and "Evaluation and monitoring" emerged as prominent themes that were the fundamental pillars of the discourse. The aggregation of codes did not simply constitute each subject; rather, each theme served as a lens that allowed the researcher to gain insight into the intricate nature of energy efficiency and key performance indicators (KPIs) in the construction of high-rise buildings.

Moreover, the aforementioned emerging themes were not arbitrarily imposed, but rather they were uncovered via the process of investigation. The motivations for their actions were not only influenced by the researcher's viewpoint, but rather derived from the inherent characteristics of the data. The primary responsibility of the researcher was to assume the position of a facilitator, adeptly maneuvering through the intricate

landscape of the academic discourse and revealing the fundamental themes and connections that permeated the extensive corpus of scholarly works.

The stage of Searching for Themes might be likened to the process of assembling a mosaic. Similar to how each individual tile adds to the overall picture, each code has played a role in the construction of themes. The artistic skill was in seeing the overarching image that materialized via the interaction of these discrete components. The researcher's capacity to see beyond superficial codes and identify emerging patterns had a crucial role in the accomplishment of this phase.

The Searching for Themes step effectively converted the research process from a compilation of separate codes into a unified and integrated story. The researcher engaged in a process of exploration, whereby they revealed the underlying structures that delineate the discourse around energy efficiency and sustainability evaluation in the context of high-rise building development. The aforementioned topics, akin to the chapters of a literary work, served as the foundational structure around which further analytical and interpretative processes were constructed. The researcher's position underwent a transformation from that of an analyst to that of a storyteller, skillfully constructing a narrative that would connect with the wider academic community and make a valuable contribution to the advancement of knowledge in the respective subject.

4. Reviewing Themes: This stage involves a deeper level of study, with the goal of carefully assessing and improving the discovered themes to achieve more depth and accuracy.

Expanding upon the topics introduced during the Searching for topics phase, the Reviewing Themes stage takes on a prominent role. The primary objective of this study is two-fold. Firstly, it aims to ensure that each theme adequately covers a wide range of concepts related to energy efficiency and sustainability evaluation in the context of high-rise building construction. Secondly, it seeks to explore the possibility of subdividing these themes into sub-themes that provide insights into specific dimensions within this discourse (Javadi & Zarea, 2016).

The method of Reviewing Themes entails doing a thorough analysis of each individual subject. This necessitates a meticulous examination of the codes and insights that contribute to the subject, aiming to ascertain if the theme effectively encompasses the wide range and complexity of the linked concepts. Moreover, it is worth considering if these themes may be further analyzed and categorized into sub-themes, therefore highlighting specific aspects within the broader framework.

As an example, let us examine a subject matter such as "Energy-efficient materials," which might be subject to critical analysis resulting in its categorization into sub-themes such as "Insulation," "Energy-conscious windows," and "Solar panels." Each sub-theme serves to define a distinct aspect of energy efficiency in the context of building materials, enabling a more comprehensive examination of intricate tactics associated with energy efficiency.

This stage calls for a level of sophistication that beyond mere categorization. It demands the capacity to discern underlying nuances and intricate layers within each thematic element. The process entails the unveiling of hidden depths of understanding that may not be readily evident yet has the capacity to enhance the examination.

Moreover, this particular stage achieves a harmonious equilibrium between augmentation and excessive fragmentation. The primary objective is to enhance the overarching themes, although caution must be used to avoid constructing an unduly convoluted network of sub-themes that might potentially diminish the fundamental essence. The sub-themes should possess unique significance while maintaining sufficient cohesion to support analytical coherence.

The Reviewing Themes step serves to enhance the depth and complexity of the theme analysis process. The statement recognizes that themes are not fixed things, but rather fluid constructions that may be refined via careful analysis. This particular stage serves as a transitional link between the initial identification of themes and the succeeding analytical stages. It facilitates the exploration of deep discoveries and a more thorough understanding of energy efficiency and key performance indicators (KPIs) within the realm of high-rise building development.

The proficiency in doing thematic analysis is contingent upon the researcher's aptitude for comprehending the intricate relationship between themes and sub-themes, so guaranteeing that each element makes a substantial contribution to the overall story. During this phase, the researcher enhances their analytical skills, which allows for a more profound investigation of the subtle complexities that define academic discourse. The Reviewing Themes stage involves the transformation of themes into dynamic and multifaceted structures that serve as the foundation for the narrative of the thesis.

The themes are as below:

- KPIs
 1. Energy

2. Emission
 3. Water
 4. Waste
 5. The quality of indoor environment
- Life Cycle Stages
 6. Product Stage
 7. Construction Stage
 8. Use Stage
 9. End of Life Stage
 - Challenges
 10. Awareness
 11. Technology
 12. Policy
 13. Finance

5. Defining and Naming Themes: The Defining and Naming Themes step included a process of improvement whereby the complex network of themes and sub-themes was condensed into precise and explicit definitions. Each definition served not only as a descriptive account, but also as a delineation that established the limits and fundamental nature of the theme element (Dawadi, 2020).

This phase focused on the preservation of coherence and the establishment of individual identities for each topic, while also preserving their interconnectedness within the broader story. The issue of "energy usage" was carefully delineated as an investigation into various techniques and procedures that promote energy efficiency, with the objective of decreasing energy consumption in the operating period of tall

buildings. The provided definition functioned as a source of clear guidance that directed the ensuing analysis.

The definitions served a crucial role in the analytical process, as they formed the foundational elements that interconnected various aspects of analysis. The inclusion of an additional level of accuracy facilitated the transformation of the study from a collection of individual findings into a unified and comprehensive investigation of energy assessment techniques.

1. Energy

Energy in the context of high-rise buildings functions as a Key Performance Indicator (KPI). It involves assessing and gauging energy usage and effectiveness over the building's lifespan. The significance lies in appraising overall energy performance and sustainability, which allows stakeholders to recognize enhancement possibilities, fine-tune energy consumption, and make prudent choices to curtail environmental repercussions and operational expenses. Observing energy KPIs is instrumental in establishing energy-saving objectives, monitoring advancements, and attaining energy-efficient, ecologically sound high-rise structures (Asdrubali & Desideri, 2019).

2. Emission

In the context of high-rise buildings, emissions pertain to the discharge of greenhouse gases and various pollutants throughout the building's existence. These emissions commonly originate from energy usage, construction materials, transportation, and waste handling. The evaluation of emissions plays a vital role in comprehending the building's environmental influence and in formulating measures to diminish the carbon

footprint and advocate sustainable approaches during the building's lifecycle (Iea, 2020)

3. Water

Within high-rise buildings, water holds significance as it encompasses the evaluation of water usage, preservation, and control. Scrutinizing water-related indicators, such as per capita water consumption, efficient fixtures, and rainwater harvesting, provides insights into the building's water sustainability. The implementation of effective water management approaches becomes crucial in lessening water squandering, endorsing conservation endeavors, and safeguarding an enduring and eco-conscious high-rise structure throughout its existence (Rofi et al., 2021).

4. Waste

Regarding waste, it involves quantifying and appraising waste production, disposal, and recycling techniques throughout the building's lifespan. Tracking waste KPIs, like diversion rates, landfill usage, and material recycling, permits stakeholders to measure the building's environmental influence and evaluate waste management efficiency. An elevated diversion rate and efficient recycling practices display a dedication to sustainable waste management, thus lessening the building's overall ecological impact and contributing to a more environmentally aware high-rise edifice (Zabalza Bribián et al., 2011)

5. Quality of Indoor Environment

For high-rise buildings, a significant KPI is the quality of the indoor environment, greatly influencing the well-being and contentment of occupants. Factors such as indoor air quality, lighting levels, thermal comfort, acoustics, and ergonomic design

are continuously monitored to ensure a wholesome and fruitful space. Proper ventilation and comfortable conditions contribute to a positive experience for building occupants. By giving prominence to and refining this KPI, stakeholders foster a more delightful and accommodating ambiance, thereby elevating overall occupant satisfaction and productivity within the high-rise structure (Al horr et al., 2016).

6. Product Stage

During the product phase the team focuses on refining the project to ensure it aligns effectively with its intended goals. They identify all the tasks that need to be completed and determine the resources required for each task. Additionally they develop a strategy, for carrying out these tasks. In a sense they also identify activities and allocate resources accordingly. This comprehensive approach leads to the creation of a project plan that outlines all the activities, tasks, dependencies and timeframes involved. The project manager plays a role in overseeing the development of a budget, for the project. This involves estimating expenses related to labor, equipment and materials. Furthermore, the construction materials are also manufactured and prepared during this phase (Imad Shakir et al., 2021).

7. Construction Stage

The construction phase of a building entails its physical realization. It comprises site preparation, resource procurement, and construction. The construction process is coordinated by the project managers and construction teams to ensure that the design purpose is achieved accurately and efficiently. This phase requires efficient project management, resource allocation and quality control to ensure the project is completed on time and within budget limitations (Crawley et al., 2020).

8. Use Stage

After construction is complete and the facility has been occupied, the use phase commences. During this phase, the energy efficacy and efficiency of the building are crucial. The management and occupants of a building play an important part in maximizing energy consumption through the application of appropriate operation and maintenance procedures. Monitoring energy consumption, instituting energy management systems, and encouraging occupant awareness and behavior modification can all contribute to energy efficiency during the use phase (Fabi et al., 2019).

9. End of Life Stage

The end-of-life phase is the concluding stage in the construction life cycle, when a structure reaches the conclusion of its functional lifecycle. The building is decommissioned, demolished, or repurposed during this phase. To reduce waste and increase material recovery, sustainable practices such as deconstruction and recycling can be utilized (Rauhala et al., 2020). Consideration of the environmental impact of the end-of-life phase is essential for the promotion of circular economy principles and the reduction of resource depletion.

10. Awareness

The assessment of high-rise building energy faces challenges due to insufficient awareness about energy efficiency and sustainability. Encouraging stakeholders to understand the advantages and cost-effectiveness can foster the adoption of eco-friendly building practices. Vital to achieving energy-efficient and environmentally conscious high-rise buildings is the promotion of education on sustainable strategies (Fouad et al., 2019).

11. Technology

The use of technology is paramount in high-rise building energy assessment, providing cutting-edge instruments to observe and enhance energy consumption. Smart building systems, IoT devices, and energy management software offer instantaneous data and discernment for well-informed choices. By incorporating sustainable technologies, such as renewable energy sources and energy-efficient systems, stakeholders attain heightened energy efficiency and sustainability in high-rise buildings (Amin et al., 2019).

12. Policy

Promoting energy assessment in high-rise buildings and advocating sustainable practices requires vital and efficient policies. Governments and local authorities play an essential role by enforcing building codes and regulations mandating energy efficiency standards, integrating renewable energy, and obtaining green building certifications. Policymakers also offer incentives and support for energy-efficient technologies and sustainable construction practices to encourage stakeholders in prioritizing energy assessment and fostering environmentally responsible high-rise buildings (Sims et al., 2018).

13. Finance

In high-rise building energy assessment, finance emerges as a pivotal player, offering essential capital for integrating energy-efficient technologies and sustainable measures. Accessing various financing options, including green loans, energy performance contracts, or incentives, facilitates easing initial expenses and motivates building owners and developers to embrace energy assessment endeavors. Financial institutions and investors take on a significant role in backing sustainable projects,

thereby enabling the construction and retrofitting of high-rise structures that prioritize energy efficiency and environmental responsibility (Liu et al., 2010).

6. Writing Up: the last stage, known as Writing Up, represented the culmination of the theme analysis process. In this context, the emerging themes assumed a prominent position, bolstered by the inclusion of perceptive quotations derived from the articles. The author adeptly integrated each thematic element into the story, resulting in a coherent and comprehensive analysis.

In-depth analyses pertaining to topics such as "materials for energy conservation," "design strategies for energy efficiency," "energy consumption," and "assessment and surveillance" shed light on the trends and findings derived from the dataset. The dynamic relationship among codes, themes, and quotations enhances the depth and authenticity of the study findings, allowing for the presentation of not just the researcher's interpretation but also the unfiltered insights derived from the data.

This stage included the process of synthesis, whereby the researcher underwent a transformation from an analyst to a storyteller. The findings derived from the theme analysis were presented in a thorough manner, enabling the reader to navigate the process of inquiry, identification of patterns, and uncovering new knowledge. During the course of the write-up, the theme analysis underwent a transition from a mere academic exercise to a thorough and substantiated investigation within the realm of scholarly discourse.

Chapter 4

RESULTS AND ANALYSIS

4.1 Introduction

This chapter presents the results of the data analysis from the identified articles. The researcher settled for a total of 69 articles where patterns in their energy assessment procedures were identified. The chapter presents the themes and sub-themes derived from the analysis. As such, it is divided into four key sections: the first addresses the energy effectiveness of high-rise structures across their entire life cycle. As previously said, a building's life cycle refers to the full process of building development, from design to maintenance. All the stages consume an amount of energy and a reduction in the consumption at each stage makes the building greener. Many researchers have identified this as an area of study in the past, making it a dominant theme in the study of energy efficiency measurement in buildings. Various sub-themes were identified under this theme and will be graphically presented in the first section. The next section will cover the Key Performance Indicators (KPIs) in high-rise buildings energy assessment. Any assessment relies on performance indicators so that the assessor can realize the actual value of a building's energy performance. The indicators could refer to the parameters that are measured to conclude whether a building is energy efficient or not. These parameters are presented as the sub-themes in this section. The last section presents the methods of energy performance assessment as covered by the previous researchers. The parameters identified need to be assessed under particular

universal standards, whether globally or within a particular jurisdiction. Therefore, this last section identifies the most common methods presented in the articles.

4.2 Energy Performance Assessment from the Perspective of High-Rise Building Life Cycle

The Figure below is a graph representing the research done on energy assessment with respect to the life cycle of a building.

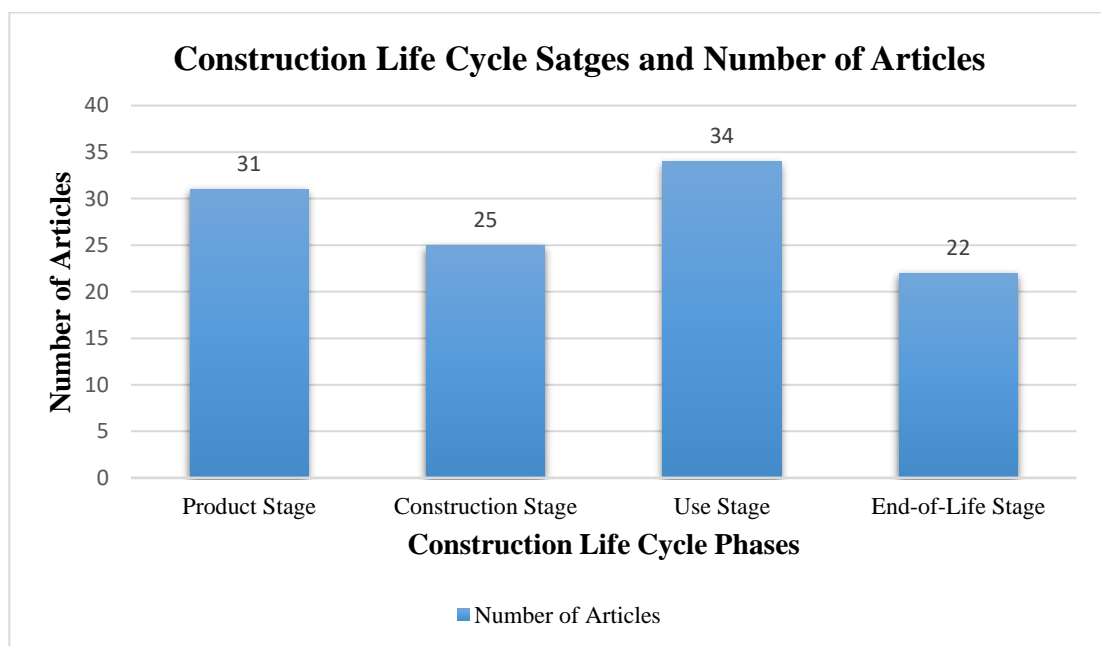


Figure 3: Number of Articles Identified Construction Life Cycle Stages.

The building life cycle refers to the four stages which a building undergoes from the time it is designed to the time it is abolished; they are product, construction, use, and end of life (WBLCA Guide Special Project Working Group, 2018). At the product stage, the construction materials are sourced and transported to the construction sites and anywhere else that they are required. This is followed by the construction stage where the raw materials are assembled according to the design and the entire installation happens according to the needs of the client. After the building is constructed, the following stage is use stage which comprises of the building operation

and maintenance period including all the repairs, replacements, refurbishments, and operational energy consumption. At the final stage which is end of life stage, the building is demolished, and the waste processed and disposed.

The results show that previous research is mainly based on the use stage (34 out of 69 articles) and product stage (31 out of 69 articles). There is less relationship between the construction stage and the energy assessment, with only 25 articles talking about this stage, while the least association is observed between energy assessment and the end-of-life stage as only 22 articles covered this stage. In addition to that, it was also apparent that a third of the articles (21/69) covered all the four stages of a building life cycle. This shows that when assessing energy it's important to consider the lifecycle of a building, than just one particular stage. Previous researchers have mainly focused on the construction and end of life stages because the construction stage involves putting materials to create a final product, which has specific goals in mind. On the hand the end of life stage is often overlooked due, to data or oversimplification (Blengini & Di Carlo, 2010).

On the hand a considerable amount of literature discussing energy assessment places an emphasis, on the utilization and design stages. When it comes to the design phase researchers mainly focus on sourcing and manufacturing materials as their sustainability performance characteristics. At the design stage, the selection of materials is a major determinant on the energy performance of the building as indicated in the second chapter. Concrete, steel, and timber high-rise building structures have different environmental impact in each of the stage of the building life cycle owing to their differences in physical, mechanical, thermal, chemical, physiochemical, and acoustical properties. Therefore, which and how materials are sourced is an important

factor for any building to be considered green, at its design phase Basbagill et al. (2013) proposed an innovative approach that integrates Building Information Modeling (BIM) and energy simulation to aid designers in predicting the decisions that influence a building's footprint. The findings from all 22 articles analyzed in this study consistently revealed that the utilization stage of a buildings life cycle has the impact compared to other stages. However, the extent of these impacts is contingent upon the choices made during the design stage, including the selection of materials and the implementation of construction techniques. Additionally the actual construction and maintenance of the building often differ from what was planned during the design phase to unpredictable occupant behaviors. This difference creates a gap, between how a building performs in reality and its projected performance based on theory.

Further examination of the findings pertaining to the utilization phase reveals that the operational energy consumption of a structure constitutes a significant proportion, ranging from 80% to 90%, of its overall environmental impact. Conversely, the embodied energy component represents the remaining portion of the building's environmental effects. For instance, a research by Russell-Smith et al. (2015) assessing the environmental performance of commercial high-rise buildings show that more than 80% of the carbon emissions and 90% of the energy consumed throughout a building's life cycle originate from the use phase. Besides, Scheuer et al. (2003) found out that 95% of the energy consumed during an entire life cycle of university buildings are from the consumption related to the operation stage. In a different study, Asdrubali et al. (2013) compared the construction and use phase and the energy consumption differences between the two stages. The results of their study showed that only 21% of the total energy consumption in a detached house comes from the construction phase

against 77% utilized during the operation phase. On the other hand, 85% of energy used in an office high-rise building was from the use phase, while only 14% was from the construction phase. A research conducted in China by He et al. (2013) examined the impact of activities, on high rise buildings. The findings revealed that a considerable portion of the waste collected (48.4%) greenhouse gas emissions (86.4%) water pollution emissions (99.2%) water consumption (77.6%) and energy consumption (68.4%) could be directly linked to day, to day building operations.

Also found in the articles is a comparative study of 13 buildings which indicated a variation between the energy consumption in various life cycle stages in residential and commercial buildings. In their study, Sharma et al. (2011) found out that a comparison of variables such as energy use ($\text{MJ}/\text{m}^2/50\text{yr}$), floor area (m^2), life time (year), building type (residential/commercial) and building location (country) shows that the total greenhouse gas emissions ($\text{CO}_2\text{eq}/\text{m}^2/50\text{yr}$) amount to 5.40 ton for the residential buildings and 5,600,000 ton for the commercial structures. The study additionally reveals that a significant proportion, specifically 80-85%, of the whole energy utilized throughout the entire lifespan of a building is expended during the occupancy phase. Bakar et al. (2015) noted that the range of Energy Efficiency Index (EEI) among 73 case buildings from 13 countries is 250-550 $\text{kWh}/\text{m}^2/\text{year}$ (primary) for office buildings, and 150-400 $\text{kWh}/\text{m}^2/\text{year}$ (primary) for residential buildings, to show that the IEE values for the residential buildings are slightly lower than that of the residential buildings.

The variations in the energy consumption between the residential and commercial buildings could be caused by the differences in the life cycles of the residential and residential high-rise buildings. Commercial buildings consume more energy because

they need more to run as compared to residential blocks because of their higher occupancy levels, high energy demands to maintain the comfortable ambience within the office premises, and the huge electrical load. Cabeza et al. (2014) show that majority of the environmental impacts covered can be linked to the electricity use and the manufacturing of the building materials. More so, the power used in the heat conduction, Heating, ventilation, and air conditioning (HVAC) systems, office waste management, concrete and paint, and manufacturing and maintenance of steel. Similarly, Pajchrowski et al. (2014) demonstrated that the environmental impacts resulting from waste disposal in buildings, energy consumption, and the use of building materials are significantly higher during the operational stage compared to the design stage, where the sourcing and manufacturing of materials take place. These impacts were found to be 12-35 times greater during the operational stage. Besides, a building's operating energy is a major contributor to the negative environmental effect.

After analyzing the articles it is clear that there is a trend indicating a preference, for avoiding the transfer of burdens when it comes to newly built structures. This trend can be seen in how a significant portion of impacts shifted from the operational phase to the phase where energy is embedded. In their study, Blengini and Di Carlo (2010) documented a notable shift in the life cycle stages of energy in both newly constructed buildings and the energy they embody. Specifically, they found that the embodied energy component accounted for 60% of the total energy consumed throughout the entire life cycle. Additionally Russell Smith et al. (2015) found that increased environmental awareness leads to adjustments in how both embodied and operational energies are allocated.

As technology advances buildings require energy over time. However this progress comes with a drawback; the use of energy materials with high insulation capacity and embodied energy. This creates a trade off between reducing energy consumption during a buildings phase and the corresponding increase in embodied energy. Therefore prioritizing embodied energy becomes essential in achieving operating energy levels. Consequently evaluating energy performance, from a life cycle perspective becomes necessary.

After conducting an investigation of the sources, it was revealed that the energy usage, during operations is influenced by several factors. These factors include the quality of outdoor air measures taken for preservation control mechanisms for motors and pumps as well as other operational methods like temperature control and regulation of air volume. The presence of HVAC systems opportunities for ventilation and energy recovery utilization of daylight and lighting control use of insulating materials, thermal mass of the building structure, characteristics of glazing and overall integrity of the building envelope also impact energy consumption (Kim & Todorovic 2013). Another important factor is the ratio between the surface area of the building envelope and its volume. This ratio significantly affects the energy demand for heating per unit area of the building. Plays a role, in determining implications during its use phase.

It can be noted from the article that there are four ways through which buildings can be made greener from the life cycle perspective: 1) changing human factors; 2) installing renewable electrical systems and other technologies; 3) adopting low-energy technologies and energy-efficient systems; and 4) reducing the demand in energy consumption (Munarim & Ghisi, 2016). However, it can be noted that an improvement in the technologies and other installations comes at an expense and negatively affects

the environment. For example, using thicker insulation material for acoustical and thermal comfort might not mean less impact to the environment because it uses more energy to obtain and install, and could have more environmental impact during disposal (Carreras et al., 2015). This implies that one shouldn't ever disregard the energy that is embedded in the materials utilized to build a building since it might result in energy savings that offset the environmental load. The assessment of energy use and environmental impact of a building from the life cycle perspective could be challenging because of the uncertainties that related to the life cycles of buildings. the importance of having an appropriate life cycle prediction cannot be more estimated. However, out of all the articles used in the current study, only 30 of them talked about building cycles within the range of 20 to 100 years. A notable proportion of the studies (33%) examined building life cycles extending beyond 50 years as the designated reference study period. Another significant portion (27%) concentrated on buildings with a life cycle ranging from 60 to 80 years. A smaller percentage (10%) utilized a reference study period below 50 years, while an additional 10% considered diverse life cycle periods as references.

4.3 Areas of Concern

The results of the systematic review shows that there can be five sub-themes under the key performance indicators, parameters which are assessed to gauge the energy efficiency of a building. They consist of energy, emissions, Indoor Environmental Quality (IEQ), waste and water. Out of the five parameters, energy is regarded as the most crucial since it directly affects the environmental performance of a building. Other important factors that have a direct and significant effect on the greenness of a building are the land or building area, and indoor environment quality. Each of the five categories can then be split into sub-categories that will form the KPIs. The table below

ranks the five parameters according to their order of importance to energy assessment and environmental assessment of high-rise buildings from the least important to the most important. There are some correlated themes, meaning a change in one could result into an automatic change of another. The KIPs, their subheadings and the number of identified articles are listed in **Table 1** below:

Table 1: List of KIP's and Identified Number of Articles

Position	Theme	Articles Identified	KPIs and the SI units
1	Energy	40	Energy supply (renewable/non-renewable %) Energy saving potentials (GJ, MWh, kWh, or %) Energy consumption (GJ, MWh, kWh)
2	Emissions	36	Greenhouse gases such as i.e. CO _{2n} , NO _n , SO _n
3	Water	21	Water supply – local, rain water (m ³ or %) Water saving potentials (m ³ or %) Water consumption (m ³)
4	Waste	18	Daily waste (kg, t) Building waste (kg, t) (generation, treatment, disposal)
5	Indoor Environment Quality	9	Ventilation Daylight Thermal comfort (°C)

The review highlights five key areas for evaluating building energy efficiency: energy consumption, emissions, Indoor Environmental Quality (IEQ), waste management, and water usage as shown in **Figure 4**. These sub-themes determine a structure's effectiveness and sustainability. Prioritizing these factors allows construction industry stakeholders to allocate resources strategically, address ecological impacts, and incorporate practices and technologies to create energy-efficient buildings with fewer emissions, better indoor environment quality, waste management, and responsible water resource use.

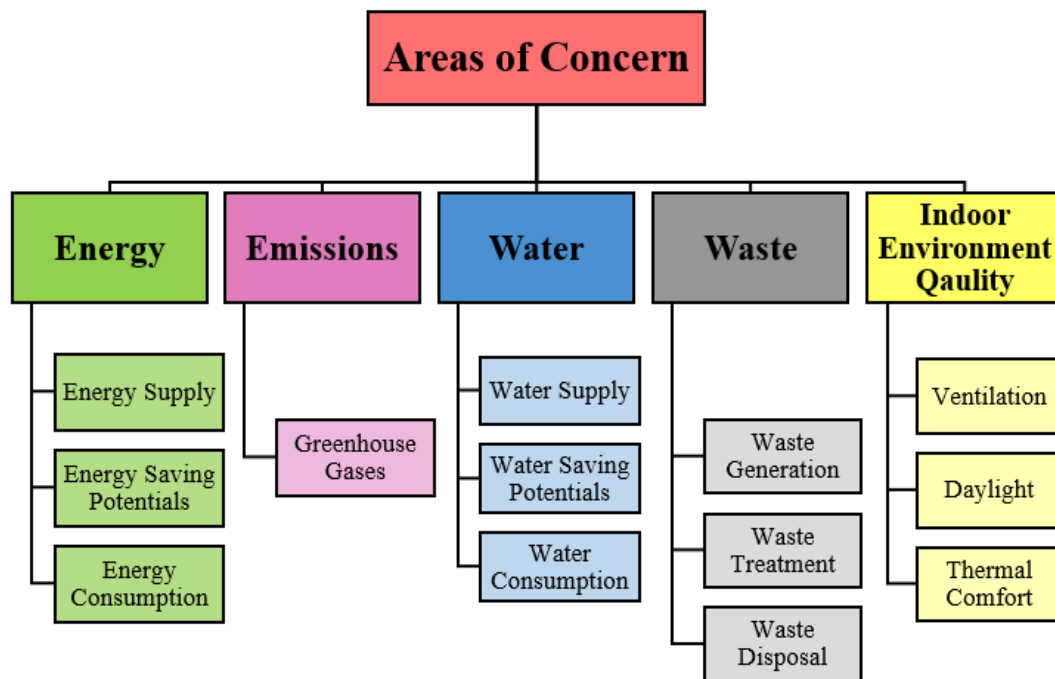


Figure 4: Areas of Concerns in High-rise Building Energy Efficiency Measures.

The findings in the above Table indicate that emissions and energy are the most dominant factors when assessing a building's energy and environmental performance. 40 articles out of the 69 selected ones included a study on energy parameter while 36 of them focused on emissions. The sub-categories under energy include energy supply, energy saving potentials, and energy consumption. The emissions category is majorly

addressed in environmental studies where the researchers are concerned about the production of greenhouse gases such as carbon monoxide, carbon dioxide, nitrogen monoxide, nitrogen dioxide, sulfur monoxide, and sulfur dioxide. Water is also an important factor ranked the third (21 articles) and under it are various sub-categories including water pollution, water supply, water saving techniques, and water consumption patterns and rates. Coming right after water was waste, ranked position 4 as it had 18 articles talking about it. It has to do with waste production, treatment, and disposal. Indoor Environment Quality appeared in 9 articles and thus ranked the 5th.

The findings also show that the area where the researchers least focused on was the indoor environment quality and potential for reuse, with 9 articles. The indoor environment KPIs include air quality, daylight, and thermal comfort. Since these elements have a direct impact on the energy consumption of a building and its overall greenness, it is grouped under the environmental category in the current study. Various studies in the past have indicated that various indoor environment qualities hugely affect the health and well-being of the occupants including noise, natural illumination and lighting, ventilation, humidity, and temperature (Cooper et al., 2021).

The provided Figure depicts the distribution of 69 articles across five research areas pertaining to energy performance key performance indicators (KPIs) in buildings.

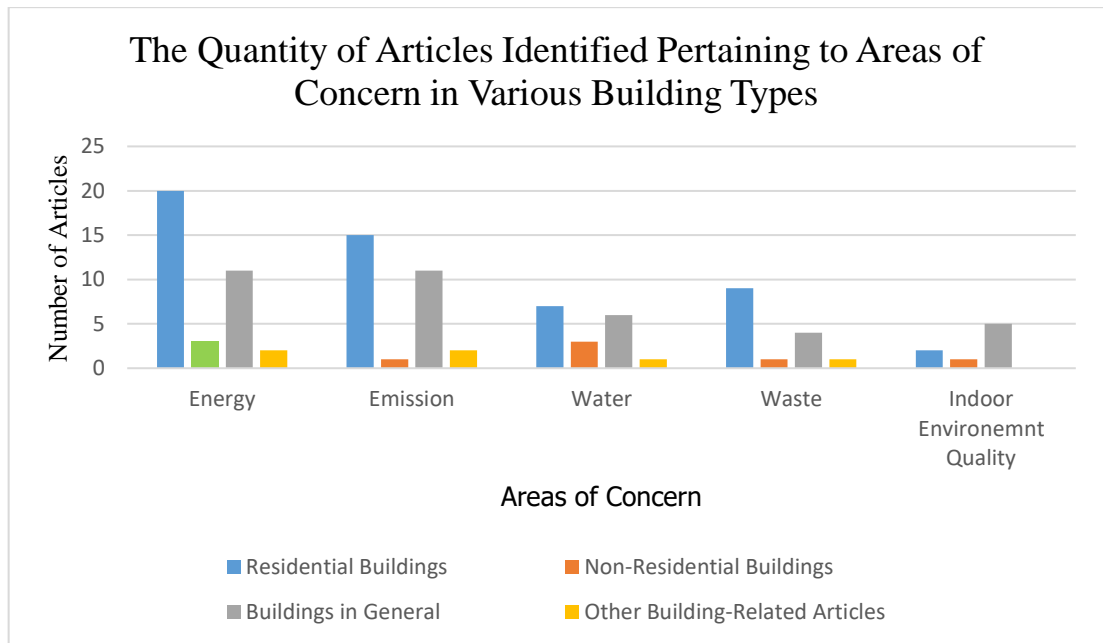


Figure 5: The Quantity of Articles Identified Pertaining to Areas of Concern in Various Building Types.

The articles on commercial and public buildings were only 5 and mostly studied water, and energy while residential buildings were 26 out of 69 and were focusing on waste, greenhouse gas emissions, and energy. On the other hand, there were 20 articles which included building simulations and models and were mostly focused on emissions and energy. It was also found out that the indoor environmental quality KPI is the most studied in the reviewed articles. 12 articles were also found to be building-related, covering general types of buildings, the tools for assessing energy performance, and sustainability present a similar tendency as the previous studies on the same topic as shown in **Figure 5**.

More analysis on the findings in the Figure above shows that majority of the previous studies on the KPIs relate to the themes of emissions and energy themes. Based on the research conducted by Bakar et al. (2015), it has been determined that HVAC systems are the predominant source of energy consumption in buildings,

followed by lighting. In their study, Cabeza et al. (2014) conducted a case analysis on six retrofitted public buildings. The research findings demonstrated that the reduction of greenhouse gas emissions and energy conservation yielded significant benefits, primarily attributed to improvements in the insulation properties of the construction structure. Additionally, it is asserted that the replacement of glazing as well as lighting components yields substantial energy advantages. In contrast, it is worth noting that both wind and solar plants exhibit higher recompense indices as well as less energy savings. Lombera and Aprea (2010) further substantiate the necessity of incorporating considerations regarding resource usage, water, and land alongside energy consumption as primary factors. The research findings pertaining to indoor environment quality indicate that when higher comfort expectations are established as the benchmarks, there is a direct correlation with energy assessment. This is because maintaining the desired comfort standards would likely require increased energy consumption by HVAC systems (Holopainen et al., 2014; Seinre et al., 2014).

The comprehensive coverage of the reuse potential is lacking. According to Napolano et al. (2015), the recycling of building materials is considered to be environmentally friendly as it serves to prevent the depletion of natural resources. The study conducted by Munarim et al. (2016) focused on the concept of reuse and involved a comparison between the rehabilitation of a building and the construction of a new building. The study revealed that the construction of a new office building would necessitate an additional 250 years to counterbalance the overall energy impact, in contrast to the conversion and refurbishment of an existing hotel building into an office space. The observed outcome can be attributed to the minimal disparity in the projected operational energy consumption between the preexisting

and recently constructed structure. Consequently, a greater amount of energy is conserved and natural resources are preserved.

The results of the systematic review show that the most dominant method of energy performance assessment is life cycle assessment. A total of 34 articles applied this method to assess the buildings. The findings of these studies corroborate the notion that the design and use phases exert the greatest influence on the life cycle of a building, while the construction and end-of-life stages have comparatively lesser impact. According to Melià et al. (2014), energy consumption is the primary determinant in the use stage.

Even though the life cycle assessment method is the dominant approach in the studies, there are several limitations related to it. For instance, the results in these studies depend on the reference study period, quality of the data collected, and the approach used. It is advisable to employ prospective scenarios as a means of conducting sensitivity assessments for buildings with extended lifespans, given the inherent impossibility of accurately forecasting consumption patterns and technological advancements over the course of a century. The studies conducted on assessments of life cycles demonstrate that energy utilization significantly influences the analysis of environmental performance, encompassing both the nature of energy used and the amount utilized. In addition, the method does not guarantee energy consumption and emission reduction but it allows for the identification of weaknesses during the construction process and suggest the possible improvements in management and technology from the perspective of sustainable development.

4.4 Energy Efficiency Measures within the KIPs

4.4.1 Energy Supply

4.4.1.1 Application of Solar Photovoltaic (PV) Systems

Solar Photovoltaic (PV) Systems are well-known as an active energy efficiency measure. Photovoltaic (PV) cells are utilized in the process of directly converting sunlight into electrical energy. Solar photovoltaic (PV) systems are commonly deployed on the rooftops or facades of tall structures in order to capture solar energy and produce sustainable electricity. Photovoltaic (PV) cells have the ability to capture solar radiation, and upon exposure to light, they induce the formation of an electric field across their layers, thereby facilitating the generation of an electric current. Through the utilization of Solar Photovoltaic (PV) Systems, high-rise buildings have the ability to mitigate their dependence on traditional grid electricity, diminish energy consumption derived from non-renewable sources, and make a valuable contribution towards establishing a more sustainable energy provision. The incorporation of renewable energy sources in the building improves its overall energy efficiency and diminishes its carbon emissions, rendering it an environmentally conscious and economically viable choice for sustainable high-rise development (Adly & El-Khouly, 2022).

4.4.1.2 Integration of Wind Turbine

The implementation of wind turbines is an active energy efficiency measure. Wind turbines are devices that convert the energy from wind into electricity. They are often placed on rooftops or near buildings to capture the winds energy and generate power. The blades of the turbine use the winds energy to spin a generator creating energy. By incorporating wind turbines high rise buildings can produce their energy reducing their dependence, on traditional power grids and promoting sustainability. The

incorporation of renewable energy sources enhances the overall energy efficiency of the structure, mitigates the release of greenhouse gas emissions, and fosters the development of a more ecologically sustainable urban setting (Asadpour et al., 2016).

4.4.1.3 Energy Storage with Batteries

Installing batteries is regarded as active energy efficiency measures within the field of energy storage solutions. Batteries serve the purpose of actively storing surplus electricity generated by Solar Photovoltaic (PV) Systems or the generators during periods characterized by reduced demand or increased production of renewable energy. Solar photovoltaic (PV) systems involve the installation of PV panels on the rooftops or facades of buildings. These panels utilize photovoltaic cells to convert sunlight into electrical energy. Photovoltaic (PV) cells have the capacity to capture solar radiation and convert it into a direct current (DC) electrical output. This DC electricity is subsequently transformed into alternating current (AC) by means of an inverter, facilitating its utilization within the premises of the building. The utilization of batteries for energy storage in high-rise buildings improves energy efficiency by effectively capturing excess renewable energy, which can be subsequently utilized during periods of high energy demand or when solar power generation is limited. The implementation of this system guarantees a dependable energy provision, alleviates pressure on the electrical infrastructure, and enhances the overall energy efficiency of the structure, thereby promoting sustainability and yielding economic benefits (Charalambous et al., 2023).

4.4.2 Energy Saving Potentials

4.4.2.1 Appliance and Equipment Replacement

The replacement of appliances and equipment for the purpose of energy saving is considered to be an effective active measure in promoting energy efficiency. The

process entails the proactive substitution of outdated and ineffective appliances and equipment with contemporary, energy-efficient models (Earle et al., 2023). The task at hand can be accomplished through the implementation of an inventory procedure, wherein all appliances and equipment within the high-rise building are thoroughly examined. This examination will involve an evaluation of their energy consumption patterns, with the ultimate goal of identifying potential areas for enhancement. The adoption of ENERGY STAR-rated appliances and high-efficiency equipment results in decreased electricity and water usage, thereby yielding financial savings on utility bills and contributing to a diminished carbon footprint. The implementation of energy-efficient appliances, including refrigerators, dishwashers, washing machines, and HVAC systems, within the high-rise building can effectively optimize energy consumption, improve overall energy efficiency, and make a valuable contribution towards achieving sustainability and environmental responsibility in its operation (Alves et al., 2018).

4.4.3 Energy Consumption

4.4.3.1 Building Automation and Controls

The implementation of building automation and controls to manage energy consumption is an active measure towards enhancing energy efficiency. The process entails the active integration of sophisticated control systems and automation technologies in order to optimize energy consumption within a tall building. The implementation of Building Automation and Controls involves the installation of various components such as sensors, smart thermostats, occupancy detectors, and automated lighting systems. These components are responsible for monitoring and adjusting energy-consuming systems within a building in response to real-time data. Through the continuous monitoring and management of energy-intensive components,

such as lighting, heating, ventilation, and air conditioning (HVAC), the building is able to enhance its responsiveness to occupancy patterns and environmental conditions in a more efficient manner. As a consequence, there is a decrease in energy wastage and an enhancement in energy efficiency. The implementation of Building Automation and Controls systems in high-rise buildings facilitates the attainment of optimal energy efficiency, the improvement of occupant comfort, and the reduction of operating expenses. This is accomplished by ensuring that energy consumption is limited to necessary times and locations, thereby promoting a more sustainable and environmentally conscious approach to building operations (Vandenbogaerde et al., 2023).

4.4.4 Green House Gas Emissions

4.4.4.1 Application of Sustainable Materials

Incorporating building materials and construction methods can help lower the carbon impact of buildings. Using materials, with carbon footprints like recycled or reclaimed ones decreases emissions during manufacturing and transportation of building elements. Additionally adopting construction practices that prioritize resource efficiency and waste reduction aids in reducing emissions (Galvin, 2023).

4.4.5 Water Supply

4.4.5.1 Water-Efficient Building Design

Water-Efficient Building Design is a passive energy efficiency measure for water supply. (Ali Muslim & Hachem-Vermette, 2023). The process entails integrating various strategies and technologies in the design phase to enhance water efficiency and minimize waste. The objective can be accomplished through the implementation of rainwater harvesting systems, greywater recycling, and the utilization of water-efficient fixtures such as low-flow toilets and faucets. In addition, it is imperative that

the design places a high priority on incorporating drought-resistant landscaping techniques and employing water-efficient irrigation methods. Through the implementation of water-efficient building design, a high-rise structure has the potential to substantially diminish its water consumption, thereby resulting in reduced energy requirements for the treatment and distribution of water. Furthermore, through the reduction of water wastage, the structure actively contributes to the preservation of the environment and augments its overall sustainability. Water-efficient building design not only enhances the energy efficiency of a building but also plays a pivotal role in advancing responsible water management and building resilience in the face of water scarcity challenges (Al-Qawasmi et al., 2019).

4.4.6 Water Saving Potentials

4.4.6.1 Smart Irrigation Systems

These systems are used to optimize the timing of watering based on weather conditions and soil moisture levels. By doing these systems help prevent watering and improve the efficiency of irrigation. This not promotes water conservation. Also indirectly contributes to energy conservation (Rao, 2020).

4.4.6.2 Water-Conserving Landscaping

Water-conserving landscaping is widely recognized as an effective strategy for actively promoting energy efficiency and achieving significant water conservation outcomes. The practice encompasses the design and management of landscapes with the objective of reducing water consumption and minimizing waste. The objective can be accomplished through the careful selection of plants that are resilient to drought conditions, the implementation of efficient irrigation methods such as drip irrigation or rainwater harvesting, and the integration of water-conservation strategies such as mulching and the utilization of soil moisture sensors. The implementation of water-

conserving landscaping in a high-rise building can lead to a reduction in water consumption, thereby indirectly impacting energy efficiency. The water utilized for landscaping purposes is commonly obtained from the municipal water supply. By reducing its usage, there is a subsequent decrease in energy consumption associated with water treatment, pumping, and distribution. Moreover, through the promotion of water conservation, the building actively contributes to broader sustainability endeavors and aids in the preservation of precious natural resources (Brelsford & Abbott, 2021).

4.4.7 Water Consumption

4.4.7.1 Water Recycling and Reuse Systems

Water recycling and reuse for water consumption is an active energy efficiency measure and it positively impacts the energy efficiency of a high-rise building in several ways. Initially, through the utilization of used water for non-potable purposes, the structure mitigates the need for fresh water resources, consequently diminishing the energy expenditure associated with water treatment and distribution. This results in a decrease in energy consumption and the subsequent reduction of greenhouse gas emissions. Additionally, water recycling systems frequently incorporate energy-efficient elements, such as pumps and filtration systems, thereby enhancing energy conservation. In addition, the implementation of water recycling and reuse strategies can effectively mitigate the strain on local water sources, particularly in regions experiencing water scarcity. This approach enhances the overall resilience of buildings in response to evolving environmental conditions. Water recycling and reuse contribute to the energy-efficient operations of a building by optimizing water usage and promoting sustainable practices (Anderson, 2003).

By adopting these techniques of recycling and reusing water resources in high rise buildings, the efficiency can be optimized impacting the environments wellbeing. The building effectively reduces the need, for using water by reusing water for cooling purposes. This helps conserve both water and energy resources. By adopting water recycling and reuse systems and this would not lessen the strain on water resources but also improve energy efficiency. It also reduces the carbon footprint associated with the energy treatment and distribution of water sources promoting a more sustainable and environmentally conscious built environment. High rise structures that implement these systems demonstrate their commitment to resource conservation and showcase a thinking mindset in addressing pressing water related issues. Additionally, these eco-friendly initiatives positively influence perception attract individuals who prioritize sustainability and enhance the buildings reputation as a socially responsible institution. The adoption of water recycling and reuse systems in high rise buildings significantly contributes to efforts, in ensuring water security combating water scarcity and promoting water management practices. This proactive approach supports the development of a sustainable future (Exall, 2004).

4.4.8 Waste Generation

4.4.8.1 Using Reusable Items

The utilization of reusable items as a means to manage waste generation is considered an effective active measure for promoting energy efficiency. The initiative entails the promotion and advocacy for the adoption of reusable items, such as coffee mugs, water bottles, food containers, and shopping bags, with the aim of mitigating the production of single-use waste and diminishing overall waste generation within a high-rise structure. The implementation of awareness campaigns, provision of reusable items to occupants and staff, and establishment of designated areas for refilling water bottles

and coffee cups can facilitate the execution of this measure. Sustainability is a focus, in high rise buildings, where reducing waste and promoting practices among residents and workers is crucial. One effective approach is source reduction, which involves reducing waste production.

To cultivate a sense of responsibility among residents it's important to educate them about waste reduction. Workshops, seminars and awareness campaigns can enlighten people about the impact of trash generation and the benefits of garbage disposal. Additionally offering guidance on garbage segregation and recycling empowers residents to effectively manage their waste. Clear signage and instructions at disposal areas facilitate waste sorting leading to improved recycling efforts and reduced landfill usage (Tafesse, 2021).

4.4.9 Waste Treatment

4.4.9.1 Waste Segregation and Sorting

Waste Segregation and Sorting for waste treatment is an active energy efficiency measure in high-rise buildings. The technique involves the methodical segregation of various waste types at their origin, promoting individuals and personnel to categorize waste into distinct groups, including recyclable materials, organic waste, and non-recyclable items. The implementation of this procedure entails the provision of appropriately designated containers for various waste categories, accompanied by educational initiatives aimed at enhancing occupants' knowledge and understanding. Through the implementation of waste segregation and sorting practices, the high-rise building can enhance waste management procedures, thereby improving the efficacy of recycling and diminishing the volume of waste directed to landfills. The implementation of this proactive approach not only enhances the effectiveness of waste treatment but also aligns with the building's broader objectives of optimizing

energy efficiency through the reduction of waste generation and its associated environmental consequences (Abdallah et al., 2020).

4.4.10 Waste Disposal

4.4.10.1 Upcycling and Circular Economy Initiatives

Upcycling and Circular Economy Initiatives for waste disposal are active energy efficiency measures that go beyond traditional waste management practices in high-rise buildings. This practice Efforts aimed at waste disposal in high-rise buildings encompass active energy efficiency measures that surpass conventional waste management practices. Rather than engaging in the mere disposal of waste materials, these initiatives prioritize the exploration of inventive methods to repurpose and reuse such materials, thereby establishing a closed-loop system that effectively mitigates the need for fresh resources. One potential strategy for incorporating upcycling and circular economy principles involves the establishment of waste exchange programs, wherein the waste generated by one entity is repurposed as a valuable resource for another entity. Furthermore, the act of coordinating donation campaigns for surplus items has the potential to redirect functional resources towards organizations or individuals who are in a state of deprivation. Through the promotion of occupant engagement in these initiatives, the building management can cultivate a culture centered around the reduction of waste and the conservation of resources within the community. The implementation of upcycling and circular economy initiatives carries substantial implications for waste management and energy conservation. Through the practice of diverting materials away from landfills and incineration, the construction of the building effectively mitigates the environmental consequences typically associated with waste treatment processes, such as the release of greenhouse gases and the generation of air pollution. Moreover, the implementation of this proactive strategy

serves to mitigate the necessity for the extraction of raw materials and the subsequent manufacturing processes, thereby resulting in diminished energy consumption and decreased carbon emissions that are typically linked to the creation of novel commodities (Rahla et al., 2021). In general, the incorporation of upcycling and circular economy principles into waste management practices not only improves the energy efficiency of tall buildings, but also supports wider sustainability objectives, thereby promoting a more resource-efficient and environmentally conscious construction industry. Through the adoption of these initiatives, the construction sector in Iraq has the potential to reduce its environmental impact, address the difficulties associated with waste management, and promote a future that is both resilient and sustainable (Minunno et al., 2018).

4.4.11 Ventilation

4.4.11.1 Designing Energy-Efficient Ventilation Systems

The primary objective of this research is to create methods that may assist in the conception of ventilation systems that are good stewards of energy. These devices have to be able to provide air while simultaneously using the very bare minimum amount of energy possible. Incorporating technology such as heat recovery ventilators (HRVs) or energy recovery ventilators (ERVs) is one approach that may be used to accomplish this goal. These technologies make it possible to transfer energy from one stream of air to another, so minimizing the amount of extra heating or cooling that is required (Calay & Wang, 2013).

4.4.11.2 Building Orientation and Design

Passive energy efficiency measures for ventilation in high-rise buildings encompass building orientation and design. These measures encompass the deliberate positioning and arrangement of the structure with respect to the trajectory of the sun, prevailing

wind patterns, and specific climatic factors in the vicinity, with the aim of maximizing the utilization of natural airflow and minimizing reliance on mechanical ventilation systems. Designers can enhance cross-ventilation in buildings by strategically aligning them to capture prevailing winds. This approach facilitates the intake of fresh air from one side while simultaneously expelling stale air from the other side. Consequently, this practice effectively regulates indoor temperatures and enhances air quality within the building. Furthermore, the strategic positioning of windows, vents, and openings facilitates the establishment of airflow pathways, thereby augmenting the efficiency of ventilation and promoting a higher level of comfort for occupants. In general, the orientation and design of high-rise buildings exert a substantial influence on their ventilation and energy efficiency, thereby promoting sustainability and environmental friendliness, as well as improving the indoor environment for occupants (Sha & Qi, 2020).

4.4.11.3 Regular Maintenance of Ventilation Systems

Regular Maintenance of Ventilation Systems is an active energy efficiency measure for ventilation in high-rise buildings. The process encompasses the implementation of regular inspections, cleaning, and maintenance activities on ventilation elements, including air filters, fans, and ductwork, with the aim of achieving optimal functionality. The implementation of a proactive approach aids in the identification and resolution of potential issues prior to their escalation, thereby guaranteeing optimal efficiency and effectiveness of the ventilation system. The enhancement of indoor air quality and occupant comfort can be achieved through the effective management of ventilation systems, ensuring their cleanliness and optimal functionality. In addition, the implementation of routine maintenance procedures serves to mitigate energy inefficiencies resulting from obstructed filters or faulty components, consequently

leading to a decrease in both energy consumption and operational expenditures. A well-maintained ventilation system plays a crucial role in enhancing the energy efficiency of a high-rise building, thereby promoting a conducive indoor environment that fosters health and productivity (Awbi, 2017).

4.4.12 Daylight

4.4.12.1 Lighting Controls and Dimming

The implementation of lighting controls and dimming techniques represents efficient active measure to improving energy efficiency in high-rise buildings. These measures involves the utilization of complicated technologies and systems to regulate artificial lighting intensities in accordance with the prevailing natural daylight conditions. In order to adjust the intensity of electric lights according to the level of natural light available in a given area, various mechanisms such as sensors, timers, and automated controls are utilized. When an adequate amount of natural light is detected, the electric lighting is adjusted to a lower intensity or completely switched off, thereby decreasing the amount of energy consumed. In contrast, during periods of limited daylight, the lighting system undergoes automatic adjustments in order to ensure the provision of adequate illumination. The integration of lighting controls and dimming techniques has the potential to greatly impact the utilization of daylight and enhance energy efficiency in tall buildings. Through the optimization of the equilibrium between natural daylight and artificial lighting, these measures effectively mitigate the overall electricity consumption associated with lighting, resulting in decreased energy expenditures and diminished emissions of greenhouse gases. In addition, the efficient utilization of daylight has been shown to improve the visual comfort, productivity, and well-being of occupants, resulting in a more enjoyable and favorable indoor environment. Inclusion of lighting controls and dimming mechanisms in high-rise

structures is an essential approach to optimize the advantages of daylighting while reducing energy consumption, thereby aligning with sustainable and environmentally conscious building methodologies (Kaminska & Ożadowicz, 2018).

4.4.12.2 Regular Maintenance and Cleaning of Windows and Skylights

Upkeep and regular cleaning are a vital passive measure for energy efficiency of high-rise buildings. In ensuring that tall buildings operate at their best in terms of performance and energy efficiency. It is extremely important to keep windows and skylights clean so that natural light can effectively brighten spaces. As time goes by these surfaces can accumulate dirt, dust and debris which hinder the transmission of light and limit the availability of daylight. By cleaning these areas not does it enhance the overall brightness, inside the building but also reduces reliance on artificial lighting during daylight hours. This leads to energy conservation and lower electricity costs. Moreover, having windows and skylights has been proven to improve the environment resulting in better well-being, productivity, and satisfaction for those inside. By prioritizing maintenance and cleaning practices, it can be achieved to ensure continuous use of natural daylight in tall buildings, thus encouraging energy efficiency and making a valuable contribution to the establishment of a sustainable built environment (De Luca et al., 2018).

4.4.12.3 Effective Window Design

Designing openings in high-rise buildings to maximize natural light is an energy-saving strategy. It involves designing the size, location, and orientation of windows to maximize natural light. By doing so, the need for illumination could be reduced during the day, which is beneficial for both the occupants and the environment. This intelligent window design not only improves comfort, but also reduces energy consumption and carbon emissions. Additionally, strategic window placement based

on the building's orientation can provide heating during the harsher months and shelter during the warmer months, resulting in overall energy savings and enhanced indoor comfort. Energy-efficient glazing materials enhance insulation. Ensures a well-distributed flow of natural light, making high-rise structures more eco-friendly and sustainable. With these window design strategies in place, energy efficiency can be achieved while simultaneously creating an interior environment that requires less artificial illumination (Far et al., 2022).

4.4.13 Thermal Comfort

4.4.13.1 Application of Air Curtains

Air curtains are an active energy efficiency measure employed in high-rise buildings to enhance thermal comfort and reduce energy consumption. These devices generate a regulated airflow that establishes an imperceptible barrier at the entrances of buildings, effectively impeding the infiltration of outdoor air and the loss of indoor air. Air curtains play a significant role in enhancing occupant comfort by effectively regulating indoor temperature and minimizing temperature fluctuations in the vicinity of entrances. Additionally, they contribute to the mitigation of strain on heating, ventilation, and air conditioning (HVAC) systems, resulting in energy conservation and decreased operational expenses. The installation of air curtains has the potential to enhance the overall energy efficiency of a tall building, thereby contributing to its environmental friendliness and sustainability. Air curtains provide an effective solution for optimizing indoor climate control and supporting energy-saving initiatives in contemporary construction practices, with the added advantage of improved thermal comfort (Far et al., 2022).

4.5 Energy Efficiency Measures within the Construction Life Cycle Stages

Within the realm of energy supply, the utilization of Solar Photovoltaic (PV) Systems and the incorporation of Wind Turbines are categorized within the product phase of the construction life cycle. During the design phase, architects and engineers conduct an evaluation of the energy demands of the building and the resources that are accessible in order to ascertain the most appropriate renewable energy systems, such as solar panels and wind turbines, to be incorporated into the building's architectural plan. In the construction phase, the consideration of incorporating Energy Storage with Batteries for energy supply is observed. The design and electrical systems of the building have been completed, and subsequently, the implementation of energy storage solutions, such as batteries, is undertaken (Kuwahara et al., 2022).

Appliance and equipment replacement is categorized as part of the use phase within the construction life cycle, specifically in relation to energy saving potentials. Once the building becomes operational, it is necessary to carry out routine maintenance and make necessary updates to appliances and equipment in order to maintain energy efficiency and achieve optimal performance in the long run (Tan et al., 2016).

In the context of energy consumption, the implementation of building automation and controls is typically incorporated during the construction phase. During this phase, the installation and integration of building automation systems are carried out to effectively regulate energy consumption, lighting, temperature, and other related systems within the building's infrastructure (Ippolito et al., 2014).

The utilization of sustainable materials is categorized within the design phase of the construction life cycle as a means to mitigate greenhouse gas emissions. Architects and designers opt for environmentally sustainable materials with reduced carbon footprints and minimized environmental impacts in the construction of buildings (Kraus & Kubečková, 2014).

During the product phase, considerations are made for water supply and water-saving potentials, which include Water-Efficient Building Design, Smart Irrigation Systems, and Water-Conserving Landscaping (Hajji et al., 2018). The incorporation of these features into the building's design aims to optimize water utilization and mitigate water consumption.

Water recycling and reuse systems are categorized within the utilization phase of the construction life cycle, specifically pertaining to water consumption (Rojas & Zhelev, 2012). Upon the building becoming operational, water recycling and reuse systems are employed in order to mitigate water wastage and foster sustainable water management practices (Sánchez-Sutil & Cano-Ortega, 2021).

According to (Amaral et al., 2020) and (Lu et al., 2023) studies, the utilization of reusable items and the implementation of on-site waste management facilities are two strategies that pertain to waste generation and waste treatment, respectively, within the use phase of the construction life cycle. In the context of construction activities, waste reduction strategies, such as the utilization of reusable materials, are implemented, alongside the adoption of on-site waste management facilities to effectively segregate and treat waste substances.

According to (Ahmed, 2023), water upcycling and Circular Economy Initiatives are categorized within the end-of-life phase of the construction life cycle, pertaining to waste disposal. Upon reaching the conclusion of the building's lifespan, these initiatives are implemented with the aim of repurposing and recycling materials, thereby reducing the amount of waste directed towards landfills and advocating for sustainable waste disposal practices.

In the context of the construction life cycle, the product phase encompasses the implementation of energy-efficient ventilation systems and the consideration of building orientation and design as means of facilitating proper ventilation (Calay & Wang, 2013). During the design phase, engineers prioritize the development of efficient ventilation systems and the optimization of the building's orientation to enhance air circulation and thermal comfort.

Furthermore, the utilization phase encompasses the regular maintenance of ventilation systems. The regular maintenance and cleaning of ventilation systems are imperative in order to optimize their performance and improve the quality of indoor air and thermal comfort for individuals occupying the building (De Luca et al., 2018).

In the utilization phase, the employment of lighting controls and dimming, as well as the regular maintenance and cleaning of windows and skylights, are encompassed. Building operators have the ability to employ lighting controls and dimming systems in order to modify the levels of artificial lighting in response to the availability of natural daylight. The implementation of routine maintenance and cleaning practices for windows and skylights is also associated with the promotion of optimal utilization of daylight and enhancement of energy efficiency (Far et al., 2022).

In contrast, Effective Window Design is categorized within the product stage. In the design phase, architects and designers meticulously strategize the placement and design of windows to optimize the ingress of natural daylight while minimizing heat gain. This approach serves to diminish reliance on artificial lighting and cooling systems (Konstantinov et al., 2019).

The implementation of Air Curtains during the construction phase is considered a viable solution for achieving thermal comfort. During this phase, the installation of air curtains is implemented to optimize thermal comfort by mitigating the heat transfer between the indoor and outdoor environments (Lowry, 2016).

4.6 Development of Generic Framework by Optimizing Key Performance Indicators and Construction Lifecycle Stages

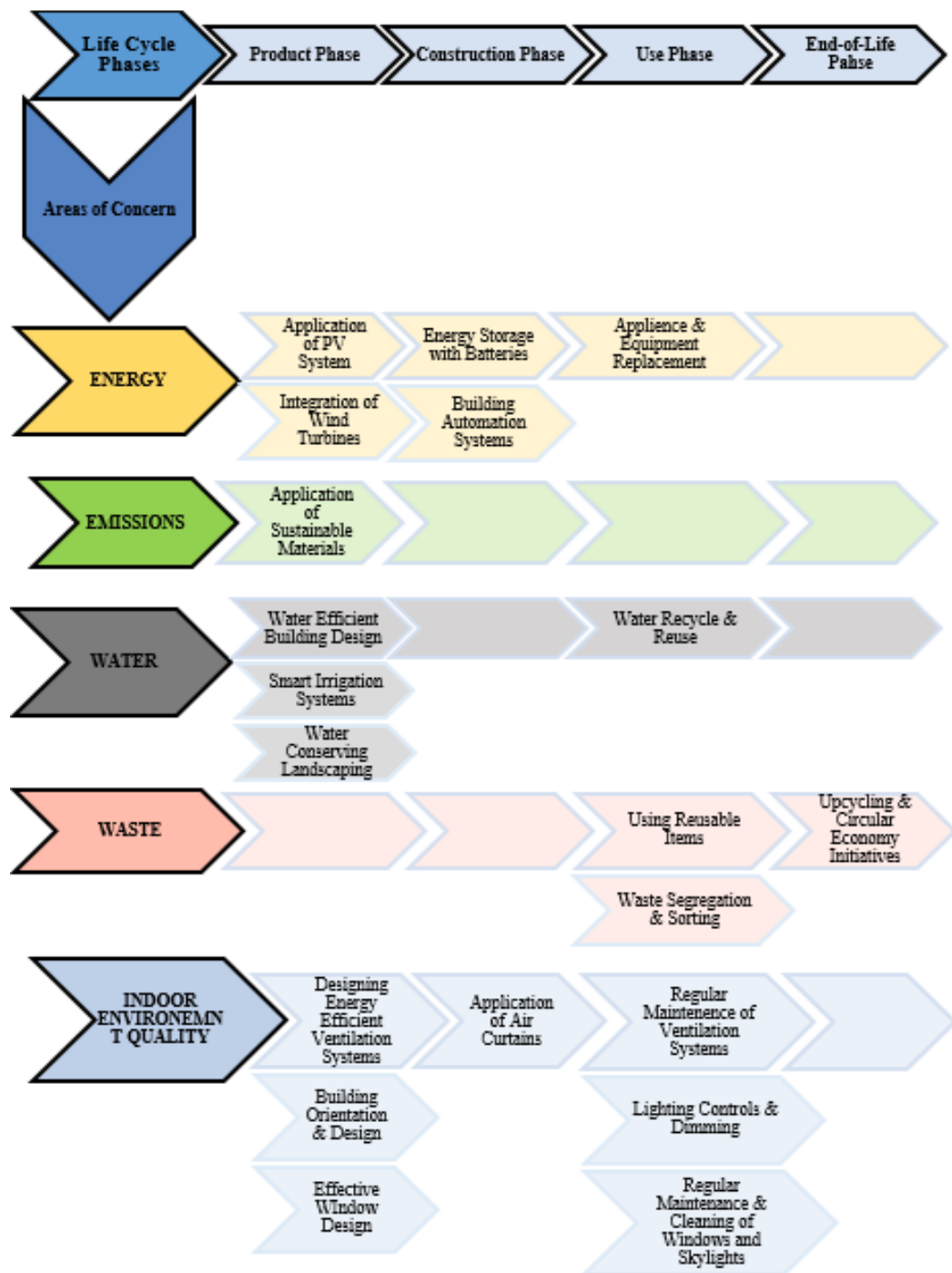


Figure 6: Generic Framework Development for Energy Efficiency Measures (KPIs and Life Cycle Construction Stages).

Figure 6 visually depicts a comprehensive and generic framework development, illustrating the integration of energy efficiency measures, Key Performance Indicators (KPIs), and various life cycle construction stages. To create an adaptable framework, for constructing high rise buildings in Iraq it is crucial to take a multifaceted approach that considers various aspects of environmental impact and resource management throughout the buildings entire lifespan. By incorporating performance indicators (KPIs) at stages of the construction process, numerous benefits could be achieved, including energy efficiency, reduced emissions, waste management, water conservation and improved indoor environmental quality.

Product Phase (Design Phase)

The integration of solar photovoltaic (PV) systems and wind turbines during the design phase of a building enables the generation of clean and renewable energy. By integrating these systems from the beginning, the building's total energy consumption from the electrical grid is diminished, leading to reduced operational energy expenses and a mitigated carbon footprint.

The incorporation of energy storage systems, specifically batteries, during the initial design phase of a building facilitates the ability to store excess energy produced by renewable sources. This feature enables the structure to enhance its self-sufficiency and resilience, particularly when faced with high-demand periods. The utilization of stored energy can be advantageous in situations where there is a decrease in renewable energy generation, thereby augmenting the energy efficiency of the building and diminishing reliance on conventional energy sources.

The implementation of sustainable materials and construction methods during the design phase has a substantial influence on the environmental performance of buildings, particularly in terms of reducing greenhouse gas emissions. The utilization of materials characterized by low embodied carbon and the comprehensive assessment of materials' life cycle contribute to the mitigation of greenhouse gas emissions over the entire lifespan of a building.

Water Supply and Potential for Water Conservation: Integration of Water-Efficient Building Design, Intelligent Irrigation Systems, and Water-Conserving Practices

Landscaping practices are implemented to optimize water usage from the outset. Water-efficient systems have the capacity to decrease water usage, resulting in energy conservation related to water heating and pumping, thereby enhancing the overall energy efficiency of the building.

Construction Phase

The incorporation of energy storage systems, specifically batteries, during the construction phase enhances energy utilization and offers temporary power supply in regions lacking grid connectivity. The management of energy use during the construction phase is also influenced by Building Automation and Controls.

The implementation of building automation and controls during the construction phase enables enhanced monitoring and management of energy consumption across diverse building systems. This facilitates the process of optimizing energy usage, resulting in a decrease in waste and an improvement in energy efficiency.

Use Phase

The subject of discussion pertains to appliances and equipment. The implementation of replacement measures during the utilization phase guarantees the utilization of energy-efficient and contemporary appliances, leading to a reduction in energy consumption and operational expenses.

Optimizing energy consumption during the operational phase of a building can be achieved through various measures, including building automation and controls, lighting controls and dimming, regular maintenance of ventilation systems, and regular maintenance and cleaning of windows and skylights. The implementation of regular maintenance practices is essential in order to optimize the operational efficiency of systems, thereby minimizing energy wastage and upholding the comfort of occupants.

Water recycling and reuse systems implemented during the utilization phase serve to facilitate the practice of sustainable water management. The implementation of efficient water utilization practices leads to a reduction in the energy demands associated with water treatment and distribution, thereby making a significant contribution towards enhancing overall energy efficiency.

The utilization of reusable items during the operational phase of a product's lifecycle serves to diminish the generation of waste and mitigate the demand for disposable materials. The implementation of On-Site Waste Management Facilities facilitates the effective segregation and recycling of waste, thereby diverting waste away from landfills and mitigating the environmental consequences associated with waste disposal.

The implementation of energy-efficient ventilation systems is crucial for achieving optimal air circulation and temperature regulation. The implementation of efficient ventilation systems has been shown to effectively decrease energy consumption related to heating, cooling, and air conditioning, thereby exerting a positive influence on the overall energy efficiency of the building.

The implementation of lighting controls and dimming techniques, in conjunction with the regular maintenance and cleaning of windows and skylights, serves to optimize the utilization of daylight while simultaneously reducing reliance on artificial lighting. This practice results in a decrease in electricity consumption and promotes the principles of energy efficiency.

End of Life Phase

The implementation of upcycling and circular economy initiatives during the end-of-life phase serves to mitigate the environmental consequences associated with waste disposal. The act of repurposing and recycling materials serves to reduce the amount of waste that is deposited in landfills, thereby promoting a more sustainable approach to waste management.

In summary, the incorporation of energy efficiency measures at various stages of a high-rise building's construction life cycle not only improves its sustainability but also directly and positively affects its energy efficiency evaluation. The implementation of these measures collectively serves to decrease energy consumption, mitigate greenhouse gas emissions, optimize resource utilization, and foster responsible waste management, thereby enhancing the environmental sustainability and energy efficiency of the high-rise building.

Chapter 5

DISCUSSION

The current study is based on an analysis of 69 articles, which serves as the fundamental basis, for the analysis conducted in the previous chapter. By reviewing a variety of reviews published in reputable academic journals it becomes evident that the chosen number of articles is significant and adequately covers the subject matter under investigation. The findings of this study offer insights into the importance of the utilization phase within a buildings life cycle. Additionally the review highlights a research gap concerning determining the duration for reference studies. This gap arises due to the variation, in building lifespans examined in these studies ranging from 20 to 100 years. Building upon this foundation this discussion aims to delve into examining developmental aspects of the proposed general framework.

This study examines aspects related to high rise building construction, in Iraq. It encompasses a range of measures such as incorporating energy sources using materials and construction techniques implementing water conserving landscaping practices utilizing intelligent irrigation systems designing energy efficient ventilation systems adopting energy storage solutions like batteries integrating building automation systems implementing energy efficiency enhancements obtaining green building certifications establishing water recycling and reuse mechanisms. Additionally it focuses on reducing waste generation by providing on site waste management facilities and segregating waste materials. Regular maintenance of building systems is also

emphasized along with controlling lighting fixtures. Ensuring cleanliness of windows and skylights. The study also involves collecting feedback and monitoring data to improve indoor environment quality. Lastly it promotes upcycling. The circular economy during the end of life phase. The goal is to explore how these measures can impact factors like energy efficiency, emissions reduction, water conservation, waste management, and indoor environment quality practices within the high rise building construction industry, in Iraq.

During an informative communication with planning director in urban planning and development in Erbil Municipality, the challenges that Iraq faces in implementing energy efficiency strategies within high-rise buildings were explained. The planning director, Aqrabi (2022), highlighted a significant issue: the lack of any set policy or regulation regarding energy efficiency in these buildings across the nation. The absence of regulations in this area not only amplifies the intricacies linked to energy usage but also emphasizes the pressing need for comprehensive frameworks to govern energy-efficient techniques. During the course of the discussion, the planning director placed significant emphasis on the delicate equilibrium that exists between the increasing need for energy in these big buildings and the urgent requirement for ecologically sustainable approaches. The conversation provided valuable insights into the complex nature of these difficulties, which include many technological obstacles, economic factors, and the need of increasing awareness among stakeholders. The director emphasized the need of using new technology and customized solutions to tackle Iraq's unique situations. Additionally, he highlighted the possible beneficial effects on the country's energy consumption patterns and overarching sustainability objectives. This conversation provides significant insights into the complex array of elements that need to be considered in order to propel Iraq towards a more energy-

efficient future within its rapidly expanding urban environment characterized by high-rise buildings.

In this study the proposed framework for implementing energy efficiency measures in high-rise buildings exhibits significant potential for revolutionizing the construction industry in Iraq and surmounting the diverse obstacles it encounters. One of the foremost challenges that needs to be addressed is the limited level of awareness regarding sustainable building practices and the advantages associated with energy-efficient technologies. The framework effectively tackles this challenge by integrating energy-efficient measures and promoting awareness campaigns and educational programs. Through the dissemination of knowledge pertaining to the economic and environmental benefits associated with energy-efficient buildings, the framework has the potential to cultivate a societal ethos centered on sustainability and motivate relevant parties to adopt environmentally conscious construction methods.

Moreover, the limited availability of cutting-edge technologies poses a substantial barrier to the implementation of energy-efficient solutions. The framework addresses this challenge by facilitating research and development in sustainable measures that can propose sustainable technologies and providing incentives for their adoption. The initiative fosters cooperation among various stakeholders including industry participants, researchers, and governmental entities, with the aim of creating and implementing cutting-edge energy-efficient solutions that are specifically designed to meet the unique requirements of tall buildings in Iraq. Furthermore, the framework places significant emphasis on the utilization of financial incentives as a means to encourage building owners and developers to make investments in energy-efficient technologies and infrastructure.

Insufficient policies and regulations within the construction industry pose a significant barrier to the implementation of energy efficiency measures. The framework tackles this challenge by promoting the establishment and implementation of comprehensive green building codes and sustainability standards. Through the incorporation of internationally recognized standards and certifications for sustainable construction, the framework has the potential to establish a regulatory atmosphere that promotes the implementation of energy-efficient strategies and incentivizes environmentally responsible building approaches.

Inadequate funding is a prevalent challenge encountered in energy-efficient construction endeavors. In order to address this challenge, by implementing the proposed framework, funding allocation for a project could be done more carefully. For some of the proposed measures there are a range of financial mechanisms, including tax incentives, grants, and low-interest loans, with the aim of providing assistance to building owners and developers in the implementation of energy-efficient measures. The provision of incentives serves to alleviate the financial strain associated with initial investments, thereby enhancing the accessibility and financial feasibility of energy-efficient technologies.

Furthermore, the framework places emphasis on implementing strategies to conserve water, minimize waste, and promote circular economy initiatives, effectively tackling the urgent challenges of water scarcity and waste management in Iraq. The framework is in accordance with the country's sustainable development goals and aids in the preservation of valuable resources by advocating for sustainable water usage and waste management practices.

In summary, the suggested framework for implementing energy efficiency measures in high-rise buildings in Iraq represents a comprehensive and strategic approach aimed at addressing the obstacles encountered by the construction industry. Through the integration of a diverse array of energy-conservation tactics, promotion of consciousness and instruction, cultivation of inventive approaches, and resolution of economic and regulatory obstacles, the framework possesses the capacity to engender a transformative change within the realm of construction. By advocating for sustainable practices and adopting energy-efficient technologies, Iraq has the potential to improve the energy efficiency of its tall buildings. Additionally, these efforts can play a significant role in global endeavors to address climate change and foster a more sustainable future for future generations. The successful implementation of the framework and promotion of sustainable development in the construction sector will heavily rely on collaborative endeavors from various stakeholders, such as the government, industry, and the public.

Chapter 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This thesis focuses on assessing energy performance in high-rise buildings to address challenges in building energy efficiency. The present thesis has effectively fulfilled the research objectives by introducing a comprehensive and flexible framework for the development of energy-efficient high-rise structures in Iraq. The study has conducted a comprehensive analysis of multiple facets pertaining to the construction of tall buildings, encompassing a diverse array of energy-efficient measures and practices that can be applied during various stages of the building's lifespan. The proposed framework seeks to attain various advantages by incorporating specific Key Performance Indicators (KPIs) throughout the construction process. These benefits encompass heightened energy efficiency, diminished emissions, efficient waste management, conservation of water, and enhanced indoor environmental quality. The conclusion of this thesis is organized in a manner that is consistent with the stated objectives of the study.

1. A comprehensive examination was done for 69 articles that have been published in esteemed academic journals. The literature review serves as the basis for the development of the framework and provides valuable insights into the importance of the utilization phase in the life cycle of a building. Furthermore, the review highlights a gap in the existing research regarding the duration of reference studies.

This gap is particularly significant due to the considerable variability observed in the building lifespans that have been investigated in the literature. This study aims to fill the current gaps in knowledge and expand upon prior research in order to make a meaningful contribution to the progress of energy efficiency in the construction of high-rise buildings.

2. A comprehensive and adaptable framework is created. The framework under consideration takes into account a range of environmental impact and resource management factors across the entire life cycle of the building, spanning from the initial design stage to the final phase of disposal. The framework endeavors to promote sustainable practices and improve decision-making processes by integrating Key Performance Indicators (KPIs) at every stage. The focal point lies in highlighting the incorporation of renewable energy sources, energy storage systems, sustainable materials, water-efficient design, water supply and treatment, and waste management strategies. The framework presents a strategic methodology that is in accordance with Iraq's sustainable development objectives and offers a roadmap for the construction of energy-efficient high-rise buildings within the country.
3. Key challenges that impede the incorporation of energy efficiency measures in the construction of high-rise buildings are identified and analyzed. The research emphasizes the difficulties associated with a lack of awareness regarding sustainable practices, limited access to advanced technologies, inadequate policies and regulations, and insufficient financial resources. The framework presents a series of effective strategies in order to address these challenges. The aforementioned strategies encompass various approaches such as conducting

awareness campaigns and educational programs aimed at promoting sustainable practices, initiating research and development endeavors to bridge technological gaps, and implementing comprehensive green building codes and sustainability standards. Furthermore, the framework proposes the implementation of financial incentives to facilitate the adoption of energy-efficient investments, while also highlighting the importance of circular economy initiatives in fostering responsible waste management practices.

In summary, this study has made a substantial contribution to the domain of energy-efficient high-rise building construction in Iraq. The framework being proposed presents a paradigm shift in addressing the various challenges encountered within the construction industry. It aims to cultivate sustainable practices and advance energy efficiency. Through the implementation of this framework and the establishment of partnerships with diverse stakeholders, such as governmental bodies, industry representatives, and the general public, Iraq has the potential to assume a pioneering role in fostering sustainability within its construction industry, thereby paving the way for a more sustainable future. The effective execution of the framework possesses the capacity to generate a more environmentally friendly and energy-efficient constructed environment in Iraq, thereby making a contribution to worldwide endeavors aimed at mitigating climate change and guaranteeing a sustainable future for future generations.

6.2 Recommendations

The findings of this study propose a generic framework that can be used for constructing high-rise buildings, in Iraq. From a perspective it would be beneficial to conduct empirical research and case studies to validate the frameworks effectiveness in real world situations. Additionally assessing the feasibility and conducting a cost benefit analysis of implementing the suggested measures will enhance the practicality and acceptance of the framework. Ongoing exploration of technologies and practices will ensure that the framework remains relevant and adaptable to future advancements in the construction industry. This study contributes significantly to the existing knowledge for policymakers, industry stakeholders and researchers by providing guidance on construction practices that can effectively address environmental challenges and promote sustainable development, in Iraq.

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