Ain Shams University
Faculty of Engineering
Architecture Engineering

Regenerative Design of Office Buildings in Cairo for Net-Positive Energy Use

A Thesis submitted in partial fulfillment of the requirement of the degree of Master of Science in Architecture Engineering

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STATEMENT

This thesis is submitted as a partial fulfillment of the Master of Science in Architectural Engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part has been submitted for a degree or a qualification at any other scientific entity.

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ABSTRACT

The consequences of unsustainable human behaviors in the climate have led to unparalleled global environmental decline. Therefore, the impacts of climate change need a particularly urgent and collective response. Unfortunately, conventional approaches to sustainability seek to mitigate or neutralize harm. Simultaneously, the building and construction sectors are seen as a significant reason for our planet's problems, particularly in a nation like Egypt, which is rapidly urbanizing and industrializing. The built environment is the biggest consumer of natural and energy resources. Regenerative design is all about understanding the ability of a building and its effect on people, communities, and other biological systems. One of the essential prerequisites for the regenerative approach is rethinking structure and health as one system. The thesis's primary goal is to establish guidelines for regenerative design by studying its concept, implementation strategies, and the fundamental principles considered in the integrated design process. To simplify the regenerative design process, a supporting tool was used, the Living Building Challenge (LBC), to discuss the net-positive energy buildings, where the buildings aim is not simply to generate energy but to identify the purpose and the way to handle resources to provide more than the building requires. A theoretical study is the foundation of the thesis approach to regenerative design and net positive energy. The thesis uses the analytical process by studying three approved office buildings as an example that includes regenerative design principles. To evaluate the efficiency of regenerative design solutions in Egypt, it was applied to an office building in Cairo and tested through a simulation program for reaching Net-Positive Energy Buildings. Finally, the thesis introduced the regenerative approach provides a unique design to interact with a living environment by emphasizing a collaborative relationship based on nature adaptation, resilience, and regeneration strategies. Also, regenerative buildings provide an opportunity to offer many services with a positive environmental impact. Therefore, designs should always consider the interconnectivity of human activities and nature, directly impacting energy consumption and the environment.

Keywords: Climate Change, Regenerative Design, Living Building Challenge Tool, Net-Positive Energy Buildings, Office Buildings.

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List Of Abbreviations

Acronym	Meaning
BEMS	Building Energy Management Systems
EUI	Energy Use Index
ERV	Energy Recovery Ventilator
EPI	Energy Performance Index
EER	Energy Efficiency Rating
EERA	European Energy Research Alliance
EESS	Electrical Energy Storage Systems
EV	Electric Vehicle
EMS	Energy Management System
GHG	Green House Gas
GCMs	Global Climate Models
GDP	Gross Domestic Product
GI	Grid Interaction
HERS	Home Energy Rating System
IAT	Indoor Air Temperature
ILFI	International Living Future Institute
IPCC	Intergovernmental Panel on Climate Change
IoT	Internet of Things
IEA	International Energy Agency
LBC	Living Building Challenge
LM	Load Matching
MMBtu	Metric Million British Thermal Unit
NZEBs	Net-Zero Energy Buildings
NPEBs	Net-Positive Energy Buildings
NCCC	National Council for Climate Change
OAT	Outdoor Air Temperature
OEM	On-site Energy Matching
OEF	On-site Energy Fraction
PEX	Polyethylene
PV	Photovoltaic
TMY	Typical meteorological year

General Introduction

- Introduction
- Problem Definition
- Thesis Value
- Thesis Question
- Thesis Main Aim and Objectives
- Thesis Methodology
- Thesis Structure

I. Introduction

Rapid population growth has contributed to the development of buildings and cities that interact little with their environment or users. In contrast, the design of buildings focuses on aesthetics, function, and fixed comfort levels. Minimal consideration has been given to whether buildings go well with and harmonize with the natural environment and human life. However, the harm caused by human activity to the world and the issues of climate change, environmental damage, and pollution may be the principal challenges of our time. So, an urgent need is to transfer to an approach that could treat and evolve social and ecological systems[1].

Regenerative thinking redefines the built environment to encompass relationships between and among structures, infrastructure, natural systems, and communities' culture, economy, and politics[2]. It redefines what sustainability means and requires within a dynamic, interdependent, and evolving world. Natural ecosystems can co-evolve into a single entity where people live in harmony with the environments they occupy. envisions the regenerative approach as a means for forming selected, mutually beneficial partnerships between humans, their constructed environment, and the natural systems of their place. The regenerative design raises the promise that buildings can "add value" and be designed and operated to generate more than is needed. The Net-positive design is not simply developing more energy but identifying the purpose and designing how the excess resources will be deployed. The Net-Positive Energy system is compatible with the essential principles of regenerative design suggested for application in an office building in Cairo by following the Living Building Challenge (LBC) framework.

This thesis explores how theoretical aspects of the Ecological Worldview may be applied to construct systematic and new design methodologies to keep up with environmental changes. Firstly, studying the regenerative design concept and its impact on improving the building environment. Climate change is one of the challenges that the regenerative system has faced in reducing energy by following Net-Positive Energy systems.

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[1] UNEP, "2021 Global Status Report for Buildings and Construction: Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sect," (Nairobi: United Nations Environment Programm, 2021).

[2]Zachary Jewison, "Regenerative Architecture: Making Nature an Equal Partner in Design" (North Dakota State University, 2019).

II. Problem Definition

Environmental issues that face the world today are climate change and its impact on human life. Population growth is one of the reasons for increasing energy use. The consequence of this usage is the significant accumulation of CO_2 emissions, causing global warming. These challenges pose a severe concern for Egypt’s future. The building and construction sector is the largest sector benefiting from natural resources regarding land use and raw material consumption. Decarbonizing the construction sector by 2050 is essential to meeting these emission reduction targets and solving the more significant climate change challenge. In 2022, building sector emissions accounted for around one-third of total energy system emissions, including building operations (26%), as well as embodied emissions (7%) from the manufacturing of materials used in their construction[3]. Mitigation and adaptation strategies are required throughout the entire building's cycle[4]. Energy is the largest source of global CO_2emissions in the built environment[5]. Egypt's energy consumption grew by 52 % between 2005 and 2021[6]. Scientific studies estimate that by 2060, due to climate change, the average temperature in Cairo is expected to increase by 4 ◦ C, and for the rest of Egypt, from 3.1 to 4.7 ◦ C.[7] As a result of high heat, the exposure of low-income populations to dangerous climatic conditions may rise tremendously.

III. Thesis Value

The regenerative design focuses more on the natural environment, which goes beyond the levels of green and sustainable design as it tends to not only produce daily life supplies such as energy and water but is designed to coevolve human systems with natural systems to generate mutual benefits and greater overall expression of life and resilience.Since

[3] IEA "The Breakthrough Agenda " in *Accelerating sector transitions through stronger international collaboration*, ed. IRENA (INTERNATIONAL ENERGY AGENCY, 2023).

[4] Ibid.

[5] Monica Crippa, "Fossil Co2 and Ghg Emissions of All World Countries," in *Publication Office of the European Union: Luxemburg*, ed. Guizzardi Oreggioni (Luxemburg: The European Union, 2019).

[6] TheWorld Bank, "Country Climate and Development Report," (Washington, DC, USA: The World Bank Group, 2022).

[7] Ahmed Ibrahim AbdelAzim, Ahmed Mohamed Ibrahim, and Essam Mohamed Aboul-Zahab, "Development of an Energy Efficiency Rating System for Existing Buildings Using Analytic Hierarchy Process–the Case of Egypt," *Renewable and Sustainable Energy Reviews* 71 (2017).

Egypt seeks to maintain the environment through the rational use of resources, the framework of Egypt Vision 2050 aims to achieve this by addressing the impact of climate change and increasing the use of renewable energy. This thesis explores how the regenerative approach strengthens the plan for Egypt's future through increasing energy and material use efficiency and reaching the standard level of interdisciplinary capacity.

IV. Thesis Question

The main thesis question is, "Can regenerative design standards be used to evaluate and improve the energy performance and reach net positive energy office buildings in Cairo, Egypt? If so, how much more possible is it to apply regenerative design techniques to establish net-positive energy office buildings in Egypt?". Attending to this question demands focusing on the following issues:

- Identifying an office building and its boundaries;
- Identifying the most effective standard of regenerative design that could reach an office building for net-positive energy use;
- Establishing a comparison between a based office building constructed and the same building, applying net-positive energy principles; and
- Establishing renewable energy sources such as PV arrays and energy storage in the office building
- Assessing the resulting overview.

Finally, the thesis steps could be included in Figure (2) below.

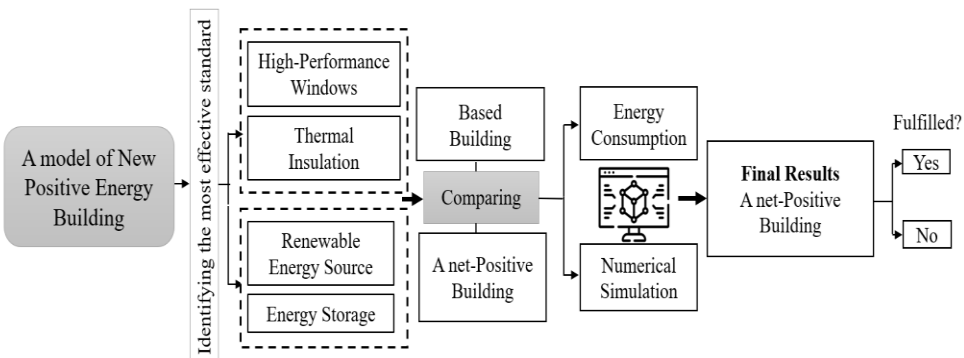

Fig.1 Flow chart of research steps used to achieve final results.[8]

[8] Author, (2024).

V. Thesis Main Aim and Objectives

➢ Main Aim

Establish design guidelines for regenerative design by applied on office buildings in Cairo to achieve Net-Positive Energy.

➢ Secondary Objectives

- Identifying regenerative design, its principles, and benefits.
- Identifying the Net-Positive Energy, its goals, strategies, and the system's framework.
- Analyzing applied examples of office buildings that reached Net-Positive energy.
- Exploring the applicability and effectiveness of regenerative design standards for achieving net-positive energy performance in office buildings in Egypt.

VI. Thesis Methodology

The study is applied research which needs an integral approach. This approach is updated to study regenerative standards based on the correlation between the scientific frame (theoretical trend) and practice (applied trend), and it permits maximum interaction between the two trends. Three methods are used to reach the final results of the thesis, as mentioned below:

➢ Theoretical Phase

- A theoretical study on the buildings' regenerative design and concept, principles, and strategies (Chapter One).
- A theoretical study on the application of Net-Positive Energy on office buildings and the framework in which the Net-Positive Energy system works. (Chapter Two).

➢ Analytical Phase

- Define the regenerative design strategy from several academic architecture design projects that applied the principles of the system for achieving Net-Positive Energy goals. (Chapter Three).

- **Practical Phase**
  - Using simulation software e QUEST and PVsyst to build and analyze the energy performance of an office building in Cairo (Chapter Four).

VII. Thesis Structure

The main goal of this thesis is achieved through its four chapters.

<u>Chapter One</u>: ***Regenerative Design: A New Mindset for Encounter Climate Change***

This chapter discusses the approach of regenerative design to reach a renewable building environment for contributing to climate change. First, present a general overview of regenerative design. Next, it reviews the main principles and definitions of regenerative design, its potential, and its importance. Finally, it discusses the regenerative approach's support tools that simplify the theoretical underpinnings of regenerative design process.

<u>Chapter Two</u>: ***Net-Positive Energy System for Office Buildings***

The second chapter reviews one of the energy field's regenerative design applications. It presents the concept of Net-Positive Energy, the differences between Net-Zero and Net-Positive energy, and how the system works in buildings.

<u>Chapter Three</u>: ***Case Studies of Regenerative Office Buildings***

As for the third chapter, the design standards for office buildings will be analyzed through environmental impact and energy consumption, which applied the standards of regenerative design and obtained the Living Building Challenge certificate to be a reference for creating Egyptian office buildings.

<u>Chapter Four</u>*:* ***Simulation Studies for Implementing Net-Positive Energy Process in Existing Office Buildings in Cairo***

Chapter four presents the results, in the form of design guidelines, for office building attainment of Net-Positive Energy, one of the applications of regenerative design discussed in previous chapters. This leads to a new mentality that can be a source of development and discussion in the field of architectural design concepts in Egypt. This chapter also includes a computer simulation study applied to an office building in Cairo, Egypt.

Main Aim	Objectives	Methodology	Chapter
Establish design guidelines for regenerative design by applied on office buildings in Cairo to achieve Net-Positive Energy.	Identifying the regenerative design and development, its principles, and benefits and support tools of it.	**Theoretical Phase**	CHAPTER 1
	Identifying the Net-Positive Energy, its goals, strategies, and the framework that the system works in it.		CHAPTER 2
	Analyzing applied examples of regenerative design in an office building. Strategies and the framework the system works in for reaching Net Positive Energy.	**Analytical Phase**	CHAPTER 3
	Exploring the applicability and effectiveness of regenerative design standards for achieving net-positive energy performance in office buildings in Egypt.	**Practical Phase**	CHAPTER 4

Fig.2: Research structure.

CHAPTER ONE

Regenerative Design: A New Mindset for Encounter Climate Change

"We are entering a time of change, when many tipping points will be passed, resulting in unexpected consequences for our way of life. However, it is a time of great opportunity, when it is possible to open up thriving if different, future."[1]

[1] Hes Dominique, "Designing for Hope: Pathways to Regenerative Sustainability," ed. Chrisna Du Plessis (Routledge, 2014).

1-1 Introduction

Over the last centuries, the increase in knowledge and technological improvements has led to the development of human societies in nature, risking natural systems. Whereas awareness of the decline of natural sources and environmental pollution. Because the built environment has played a vital role in the climate problem, the World Health Organization has designated climate change as the twenty-first century's most significant global health threat. Climate change's conquests will influence human life and health in practically every possible aspect, from water access to agriculture and food supply to risking the future of cities and infrastructure.

The regenerative approaches seek to design human systems that can co-evolve with natural methods to generate mutual benefits and a greater overall expression of life and resilience. The regenerative development and design fieldwork on the self-regulation of biological living systems. Experts are developing new design and construction support tools for regenerative approach principles. At the same time, emerging design support tools showcase essential features and attributes and assist practitioners, designers, and stakeholders.

This chapter's purpose is to present the consequences of climate change on humans and the environment. An overview of regenerative design and development by studying their main principles and definitions. Moreover, it compares the support tools of regenerative design and the suitable tool for the regenerative approach.

1-2 Climate Change

The terms "climate change" and "global warming" are frequently used interchangeably and include different physical occurrences and public policy issues[1]. According to the United Nations Framework Convention on Climate Change, climate change is " directly or indirectly attributable to human action that changes the structure of the global atmosphere, and that is in reserve to natural climate variability observed over comparable periods[2]." In addition, the Intergovernmental Panel on Climate Change (IPCC) publishes a report on the form of climate change

[1] TheWorld Bank, "Country Climate and Development Report," (World Bank publications, The World Bank Group, Washington, DC, USA …, 2022).

[2] United nation environment, "2021 Global Status Report for Buildings and Construction: Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sect," (Nairobi: United Nations Environment Programm, 2021).

science every six to seven years. Several surveys have reached a consensus of 97%, with 90–100% of experimental evidence indicating that humans are the primary source of global warming[3].

According to IPCC, total net anthropogenic GHG emissions have persisted to increase from 2010–2019, which were higher than in any previous decade[4]. One of the causes of raising the atmosphere's carbon dioxide, based on the International Energy Agency (IEA); the energy sector is the basis of around three-quarters of greenhouse gas emissions[5]. That caused much environmental and human damage[6]. It expects the atmospheric CO_2 concentration to continue to increase over the coming decades[7]. Unfortunately, past increases in CO_2 concentration and likely future increases will continue to push temperatures up, leading to rising sea levels and more extreme weather[8].

Egypt's total greenhouse gases emissions rose from 134 million tones (Mt) of carbon dioxide equivalent (CO_2 e) in 1990 to 352 Mt CO_2 e in 2019, representing a 0.73 % share of global emissions[9]. Energy is the largest source of global CO_2 emissions in the built environment[10]. Egypt's energy consumption grew by 52 % between 2005 and 2021[11]. Gas consumption in Egypt has been increasing steadily but soared in recent years. The energy usage in Egypt goes to buildings at a rate of 67%, especially for office buildings that rapidly grow in new business areas. The direction that future human activities take will determine how severe the

[3] Valérie MassonDelmotte, "Climate Change 2021: The Physical Science Basis," in *Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change*, ed. Panmao Zhai, et al. (2021).

[4] IPCC, "Climate Change 2022 Mitigation of Climate Change Summary for Policymakers," (IPCC, 2021).

[5] Stéphanie Bouckaert, "Net Zero by 2050: A Roadmap for the Global Energy Sector," ed. Araceli Fernandez Pales (IEA, 2021).

[6] IEA "World Energy Outlook 2022," (IEA, Paris, France, 2022).

[7] R Pindyck, "Climate Future: Averting and Adapting to Climate Change," *Oxford University Press. Ramsey, F.,(1928): A Mathematical Theory of Saving, Economic Journal* 38 (2022).

[8] Raymond Cole, "Navigating Climate Change: Rethinking the Role of Buildings," in *Sustainability* (2020).

[9] The World Bank, "Country Climate and Development Report," (World Bank publications, The World Bank Group, Washington, DC, USA …, 2022).

[10] Monica Crippa et al., "Fossil Co2 and Ghg Emissions of All World Countries," Publication Office of the European Union: Luxemburg (2019).

[11] The World Bank, "Country Climate and Development Report," (World Bank publications, The World Bank Group, Washington, DC, USA …, 2022).

effects of climate change are. More climatic extremes and extensive negative repercussions on our planet will result from increased greenhouse gas emissions[12]. However, the extent to which the emission of carbon dioxide will determine these long-term repercussions[13]. So, if possible, to lower emissions, it can avoid some of the worst outcomes. First, the thesis discusses one of the fundamental causes behind the climate crisis, “buildings’’ and the impact of climate change on the environment and humans. Then, it discusses possible solutions to help Egypt overcome climate change.

1-3 Impact of Climate Change

Climate change has a noticeable impact on several societally significant sectors, including human health, agriculture, food security, water supply, transportation, energy, biodiversity, and ecosystems. Moreover, these impacts are predicted to become much more disruptive in decades[14]. Natural and human systems are strained beyond their capacity to adapt. At the same time, increased human emissions of heat-trapping greenhouse gases are already altering the Earth's climate and significantly impacting the environment[15]. The extensive adverse effects, associated losses, and harm are made to the environment and people beyond natural climatic variability. Some development and adaptation efforts have reduced vulnerability. However, biological and human systems are strained beyond their capacity to adapt.

Africa and South/Southeast Asia are the regions most threatened by climate change, and these regions have the least ability to prevent or mitigate the effects of climate[16]. Furthermore, it is estimated that by 2050 these areas will be home to almost all of the additional 2.5 million urban

12 Mohammad Fahmy et al., "A Review and Insights for Eleven Years of Urban Microclimate Research Towards a New Egyptian Era of Low Carbon, Comfortable and Energy-Efficient Housing Typologies," *Atmosphere* 11, no. 3 (2020).

13 Bassent Adly and Tamir El-Khouly, "Combining Retrofitting Techniques, Renewable Energy Resources and Regulations for Residential Buildings to Achieve Energy Efficiency in Gated Communities," *Ain Shams Engineering Journal* 13, no. 6 (2022).

14 Monica Crippa et al., "Fossil Co2 and Ghg Emissions of All World Countries," *Publication Office of the European Union: Luxemburg* (2019).

15 Intergovernmental PanelonClimate, "Climate Change 2022 Mitigation of Climate Change Summary for Policymakers.," (2022).

16 Monica Crippa et al., "Fossil Co2 and Ghg Emissions of All World Countries," Publication Office of the European Union: Luxemburg (2019).

residents[17]. As a result, decision-makers, communities, and local governments are under increased pressure to appropriately handle these hazards and protect their citizens' safety and well-being due to the rise in storm occurrences that coincides with increased urbanization and population expansion[18].

1-4 Buildings and Climate Change

The building and construction sector is the largest sector benefiting from natural resources regarding land use and raw material consumption. Decarbonizing the construction sector by 2050 is essential to meeting these emission reduction targets and solving the more significant climate change challenge. In 2022, building sector emissions accounted for around one-third of total energy system emissions, including building operations (26%), as well as embodied emissions (7%) from the manufacturing of materials used in their construction.[19] Building operations and construction emissions account for more than one-third of global energy-related emissions. Mitigation and adaptation strategies are required throughout the entire building's cycle[20].Global energy-related CO2 emissions increased by 1.1% in 2023, totaling 410 million tons (Mt) and setting a new record high of 37.4 billion tons figure (1.1). This compared to a 490 (Mt) growth in 2022 (1.3%)[21]. Coal-related emissions accounted for more than 65% of the rise in 2023[22]. The global shortage in hydropower generation due to droughts increased emissions by around 170 Mt. Without this effect, global electricity sector emissions would have dropped by 2023[23].

[17] The World Bank, "Country Climate and Development Report," (World Bank publications, The World Bank Group, Washington, DC, USA …, 2022).

[18] Raymond J Cole, "Navigating Climate Change: Rethinking the Role of Buildings," Sustainability 12, no. 22 (2020).

[19]IEA, "Co2 Emissions in 2023," in *A new record high, but is there light at the end of the tunnel?* (INTERNATIONAL ENERGY AGENCY, 2023).

[20] IEA, "The Breakthrough Agenda Report," in Accelerating Sector Transitions Through Stronger International Collaboration, ed. IRENA (INTERNATIONAL ENERGY AGENCY, 2023).

[21] IEA, "Co2 Emissions in 2023," in A new record high, but is there light at the end of the tunnel? (INTERNATIONAL ENERGY AGENCY, 2023).

[22] Ibid.

[23] Ibid.

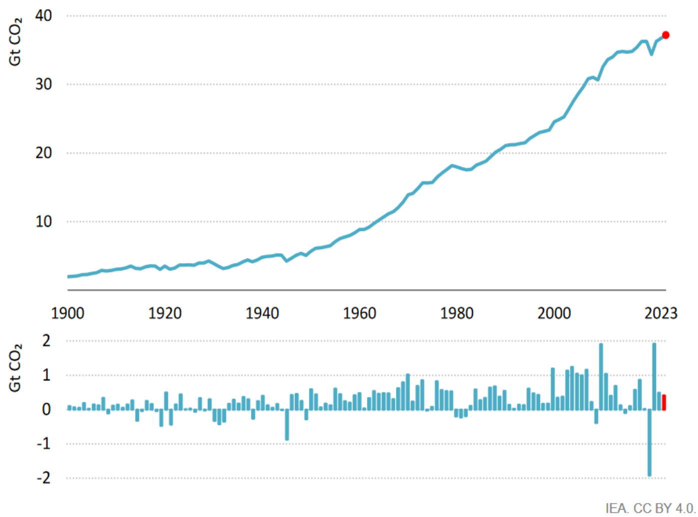

Fig.1.1: Global energy-related CO_2 emissions and their annual change, 1900-2023[24].

In Egypt, as figure (1.2) the sector of the building has an emission of 8.5% and the sector of electricity has an emission has 40.9% based on the Ministry of Petroleum & Mineral Resources[25]. depicts the linkages of climate change drivers to the environmental effects of climate change and how it impacts buildings and the people and processes within Global material usage is anticipated to more than quadruple by 2060.

So, needing to consider the mutual interaction between the built environment, the inhabitants, and nature. Mitigation and adaptation must be pursued actively to address and respond to the current and future climate threats. Future-proofing the building sector should be a centerpiece of building resilience and GHG emissions mitigation[26].

[24] Ibid.

[25] Ministry of Petroleum & Mineral Resources, "Statistical Yearbook-Environment," (Central Agency for Public Mobilization and Statistics: Central Agency for Public Mobilization and Statistics, 2024).

[26] Jaume Salom et al., "An Evaluation Framework for Sustainable Plus Energy Neighbourhoods: Moving Beyond the Traditional Building Energy Assessment," *Energies* 14, no. 14 (2021): p 25.

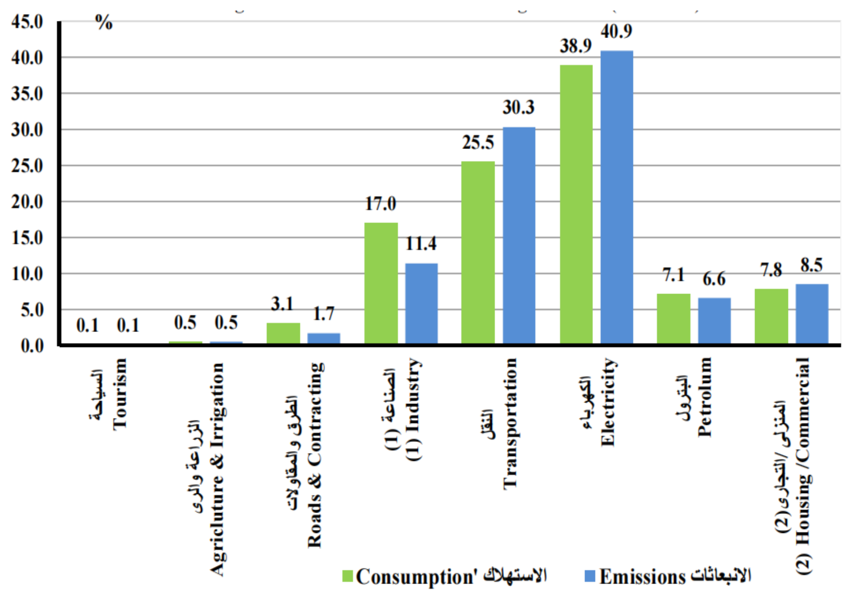

Fig.1.2: Sectoral distribution of consumption of petroleum products, gas and resulting carbon dioxide emissions according to sectors in Egypt. [27]

In this regard, reducing the amount of greenhouse gases (GHG) produced into the atmosphere is one of the most effective strategies for individuals to live an ecologically friendly existence[28]. Unplanned buildings with no built-in ecological design require more energy. Increasing energy use raises energy demand and GHG emissions, exacerbating the effects of global warming. In figure (1.3) shows how climate change could affect in buildings and people and processes. As a result, this sector provides significant energy savings and minimizes GHG emissions[29]. Building design and planning techniques should address the climatic issue and those that prevent or slow the development of future pandemics, all while social, economic, and political instability grows[30].

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[27] Ministry of Petroleum & Mineral Resources, "Statistical Yearbook-Environment," (Central Agency for Public Mobilization and Statistics: Central Agency for Public Mobilization and Statistics, 2024).

[28] United nation environment, "2021 Global Status Report for Buildings and Construction: Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sect," (Nairobi: United Nations Environment Program, 2021).

[29] Ahmet Tarık Usta and Mehmet Şahin Gök, "Climate Change Mitigation Technologies Detection and Evaluation: Case of Buildings," *Kybernetes* (2022).

[30] Raymond J Cole, "Navigating Climate Change: Rethinking the Role of Buildings," Sustainability 12, no. 22 (2020).

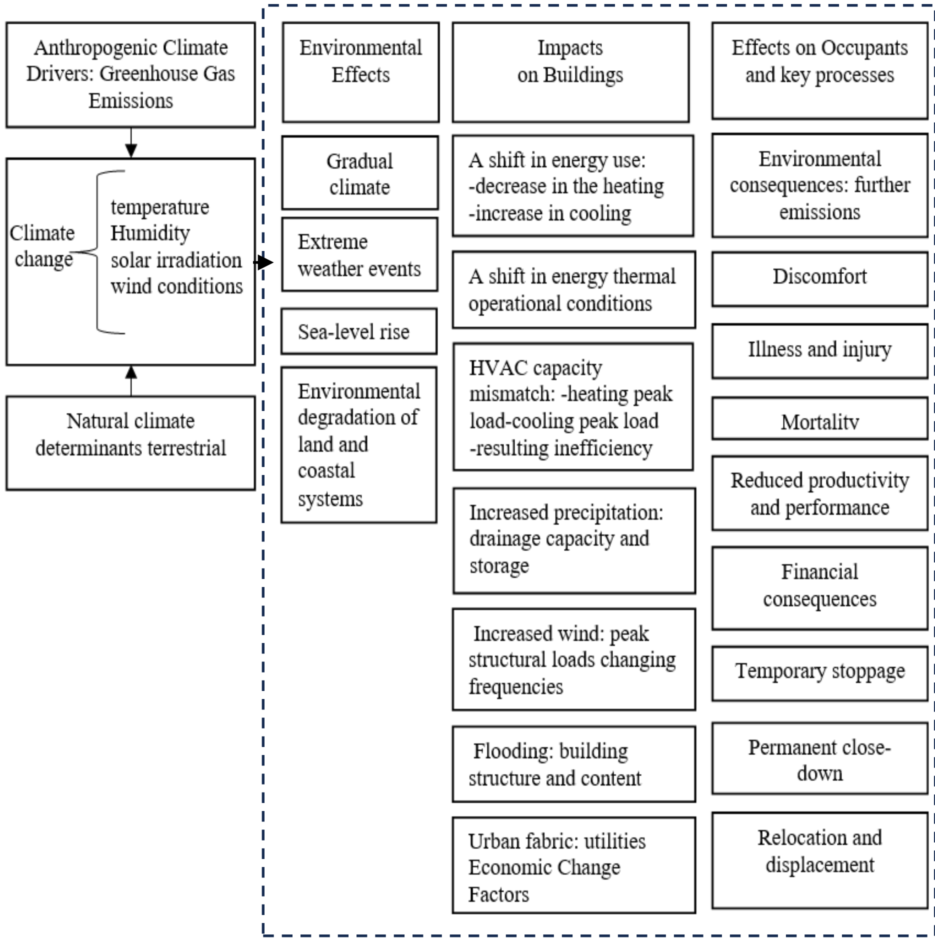

Fig. 1.3: How the environmental impacts of climate change affect buildings and the people and processes[31].

1- 5 Impact of Climate Change on Temperature

Based on the IPCC’s sixth assessment report, risks escalate with additional near-term warming in all regions and domains[32]. Certain species and ecosystems, especially those in arctic and already-warm regions, may suffer without immediate and significant emissions reductions. Unique and

[31] United nation environment, "2021 Global Status Report for Buildings and Construction: Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sect," (Nairobi: United Nations Environment Program, 2021).

[32] Intergovernmental panel on climate, "Climate Change 2022 Mitigation of Climate Change Summary for Policymakers.," (Intergovernmental panel on climate, 2022).

threatened ecosystems are at high risk[33]. Scientists have high confidence that the rise in global temperatures, which are mainly caused by greenhouse gases produced by human activity, will last for many decades. However, human emissions of heat-trapping gases have warmed the climate. By nearly 2 degrees Fahrenheit (1.1 degrees Celsius) through pre-industrial times (starting in 1750). The global average temperature will reach or exceed 1.5 °C (about 3 degrees F) within the next few decades[34] as shown in figure (1.4).

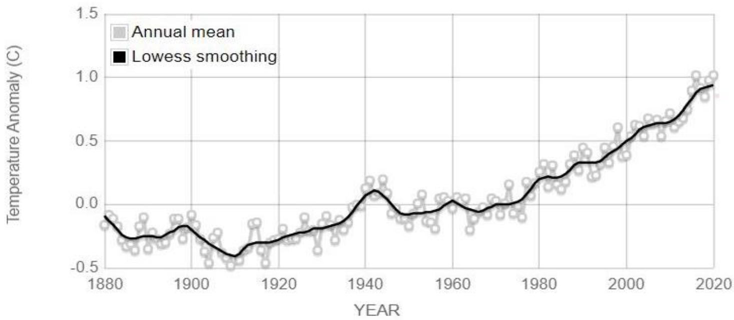

Fig.1.4: Global temperature per the years. [35]

In 2011-2020, the global surface temperature was 1.09 [0.95 to 1.20] °C higher than in 1850-19006, with greater increases over land (1.59 [1.34 to 1.83] °C) than over the ocean (0.88 [0.68 to 1.01] °C)[36]. The global surface temperature in the first two decades of the twenty-first century (2001-2020) was 0.99 [0.84 to 1.10] °C higher than in 1850-1900. Since 1970, global surface temperature has risen faster than in any other 50-year period over the last 2000 years[37].

Temperatures have a considerable impact on energy sector emissions because they affect the demand for heating and cooling.2023 was the warmest year on record[38]. However, 2022 was also highlighted by unusually high temperatures and a high ownership rate of air conditioning[39]. In contrast, these will affect all regions of Earth. According to the German Climate Service Center's 32 Global Climate Models (GCMs) research, Egypt's annual mean temperature will rise by 1.8°C to

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[33] Ibid.

[34] Ibid.

[35] Nasa, "Global Temperature " Https://climate.nasa.gov.2022.

[36] IPCC "Climate Change 2023," in *Synthesis Report* (IPCC, 2023).

[37] Ibid.

[38] IEA, "Co2 Emissions in 2023," in A new record high, but is there light at the end of the tunnel? (INTERNATIONAL ENERGY AGENCY, 2023).

[39] Ibid.

5.2°C by the 2080s[40].Where temperatures in Egypt will continue to rise through the end of the century under all emission scenarios. Also, there will be a significant increase in the intensity, frequency, and length of heat waves. Increased heat and extreme heat conditions will significantly affect human and animal health, agriculture, water resources, and ecosystems. Egypt's government seeks to limit global warming to below 2 degrees Celsius and work hard to keep the 1.5 degrees Celsius target alive[41].

1-6 Egypt's Role in Facing the Climate Crisis

Egypt is taking action to hasten the shift to a development model that is more environmentally friendly, resilient, and inclusive. Egypt is committed to providing its fair share of climate action as part of the worldwide effort to combat climate change. It is important to note that all facets of society, not only government organizations, required participation in Egypt's national climate change policy implementation, including civil society and non-governmental organizations.

Since the affected of Egypt by climate change, coping with its adverse effects is a vital necessity. Therefore, Egypt created its first National Strategy for Disaster Risk Reduction and Climate Change Adaptation in 2011. In addition, a Low Emission Development Strategy (LEDS) was issued in 2018, which was prepared to align with the Sustainable Development Strategy SDS - Egypt Vision 2050[42]. Despite this, there still needed to be a gap in consolidating all aspects of climate change in one document to be an essential reference that ensures the integration of the climate change dimension into the general planning of all sectors in the country.

As a result, the National Council for Climate Change (NCCC) has asked to create Egypt's first thorough national climate change strategy, which will last until 2050. In light of the role of Egypt in encountering climate change, plans to host the twenty-seventh session of the Conference of Parties (COP 27) held from 6 to 18 November 2022 in Sharm El-Sheikh, Egypt. This conference is one of the largest global annual conferences for

[40] Hans O Pörtner, "Climate Change 2022: Impacts, Adaptation and Vulnerability," ed. Debra C Roberts (IPCC, 2022).

[41] Stéphanie Bouckaert, "Net Zero by 2050: A Roadmap for the Global Energy Sector," ed. Araceli Fernandez Pales (IEA, 2021).

[42] Arab Republic of Egypt Ministry of Environment "Egypt National Climate Change Strategy 2050," (Arab Republic of Egypt Ministry of Environment, 2022).

seeking to accelerate global climate action through emissions reduction, scaled-up adaptation efforts, and enhanced flows of appropriate finance.

1-7 A New Mindset to Design Regenerative Buildings

The urgency resulting from collective inactivity on climate change necessitates bigger and faster advancements in efforts, where our collective inaction has profound repercussions. According to the book Hope Is an Imperative[43], "The urgency created by the world's inaction on climate change calls for more significant and quicker progress in efforts." However, unfortunately, profound consequences result from collective inaction on climate change[44]. However, despite several countries demonstrating their attempt to mitigate the impact of climate change, to maintain the potential of reducing global warming to a somewhat safe 1.5-degree increase, global GHG emissions should now be reduced by 7.6% per year between 2020 and 2030[45].

Addressing the climate crisis requires bold and rapid collective action. Buildings are essential components of collective cultural memory that represent society's values and technological prowess during construction[46]. It also reflects on how important environmental issues are to the community. Some significant societal challenges and the concepts and language employed in building design in response to schematic positioned throughout the last 50 years[47].

Although it is given chronologically for ease of reference, many overlap, coexist, mature, reappear in other forms, and can be interpreted in various ways. Before were categorized as "green" buildings in the 1990s, for instance, buildings that prioritized particular performance issues were described as "low energy," passive solar, "daylit," and "healthy" in the 1970s and 1980s[48]. Similar to how the necessity for adaptation came before climate change mitigation, they are now seen as necessities. Numerous

[43] David W Orr, *Hope Is an Imperative: The Essential David Orr* (Island Press, 2011).

[44] Hes Dominique, "Designing for Hope: Pathways to Regenerative Sustainability," ed. Chrisna Du Plessis (Routledge, 2014).

[45] Raymond Cole, "Navigating Climate Change: Rethinking the Role of Buildings," *Sustainability* 12, no. 22 (2020).

[46] Ibid.

[47] Shady Attia, *Regenerative and Positive Impact Architecture: Learning from Case Studies* (Springer, 2018).

[48] Raymond J Cole, "Navigating Climate Change: Rethinking the Role of Buildings," Sustainability 12, no. 22 (2020).

occurrences, discoveries, and advancements have impacted public attitudes and the importance of environmental issues since the 1960s. As a result, these have influenced building design and construction methods[49]. As a result, practitioners tried to direct the old depleting system into a new system that entails abandoning previous convictions rather than consuming and utilizing all around us for human benefit, but by viewing the city as a source rather than a drain. So, first and foremost, it should be aware of an ecologically responsible worldview[50].

1-8 Evolution of Ecologically Responsible Paradigms

The concept of ecologically responsible design evolves through multiple paradigms, each with several different trajectories. Each of the three paradigms of ecologically responsible design has its own evolutionary path, as shown in figure (1.5).

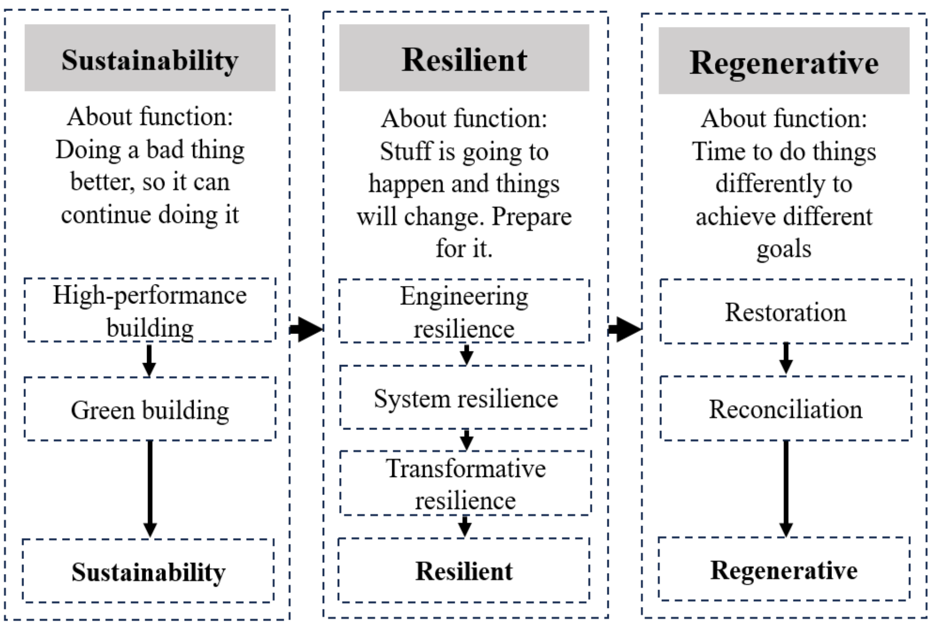

Fig.1.5: Evolution of the three principal paradigms in isolation. [51]

[49] Du Plessis Chrisna "Towards a Regenerative Paradigm for the Built Environment," *Building Research & Information* 40, no. 1 (2012).

[50] Timea Kadar and Manuella Kadar, "Sustainability Is Not Enough: Towards Ai Supported Regenerative Design" (paper presented at the 2020 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), 2020).

[51] Chrisna Du Plessis, "The City Sustainable, Resilient, Regenerative–a Rose by Any Other Name?," in *Design for Regenerative Cities and Landscapes* (Springer, 2022).

A- Sustainability Conception:

- How construct human habitats impacts the natural environment and the health of the people who live in these habitats[52].

- The resources rely on to provide modern habitats are limited. As a result, the original solution was to improve building performance by making them more energy efficient, improving air quality and natural light, and enhancing efficiency[53].

However, it was discovered that structures and cities had significantly larger ecological footprints due to material lifecycles, energy sources, and land use changes. A set of measuring and management tools created to stimulate the adoption of new measurements and technology. The green building sector has become a significant force in enhancing the performance of the primary production and consumption systems. Sustainability is defined as continuing present development routes within safe and just operating areas[54].

B- Resilience Conception:

A system's characteristics determine its capacity to take in, adjust, or transform in reaction to internal or external disturbances. It is an attribute that results from the configuration of the system. Its three main forms demonstrate a departure from engineering resilience, which strives to enhance mechanical systems and infrastructure, to a particular disturbance by enhancing systems resilience, transformative resilience, efficiency, consistency, and predictability[55]. The final two conditions recognize the complexities of social-ecological systems. Its systems go through cycles of change, including gradual and cumulative modifications and sudden changes, and its resilience arises from its tenacity and flexibility[56].

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[52] Aysegul Akturk, "Regenerative Design and Development for a Sustainable Future: Definitions and Tool Evaluation" (University of Minnesota, 2016).

[53] Maria Beatrice Andreucci et al., *Rethinking Sustainability Towards a Regenerative Economy* (Springer Nature, 2021).

[54] Chrisna Du Plessis, "The City Sustainable, Resilient, Regenerative–a Rose by Any Other Name?," in *Design for Regenerative Cities and Landscapes* (Springer, 2022), p 26.

[55] Akturk Aysegul, "Regenerative Design and Development for a Sustainable Future: Definitions and Tool Evaluation" (University of Minnesota, 2016).

[56] Raymond J. Cole, "Regenerative Design and Development: Current Theory and Practice," *Building Research & Information* 40, no. 1 (2012).

Design for resilience focuses on modifying the system's structure such that its webs are more spread out and variety is built into the system's segments. The next step in developing resilience thinking was discovering that stability is neither good nor bad. Long-term pressures include climate change, growing urbanization, and pervasive urban poverty (including a lack of quality education, vital services, and safety).

C- Regenerative Conception:

The regenerative paradigm emerged as a result of the recognition that more is necessary to have a Net-Positive impact. It was necessary to create a new model in order to render the previous model obsolete. The first stage would be to reinvent humans' role in the greater global ecosystem, changing the human species from adversary in the story to productive members of the community of life by healing what needs to be healed and reconciling human and environmental values and aims[57].The conditions for a new life are established, allowing human and natural systems to continue co-evolving and interacting constructively. As indicated in figure (1.6).

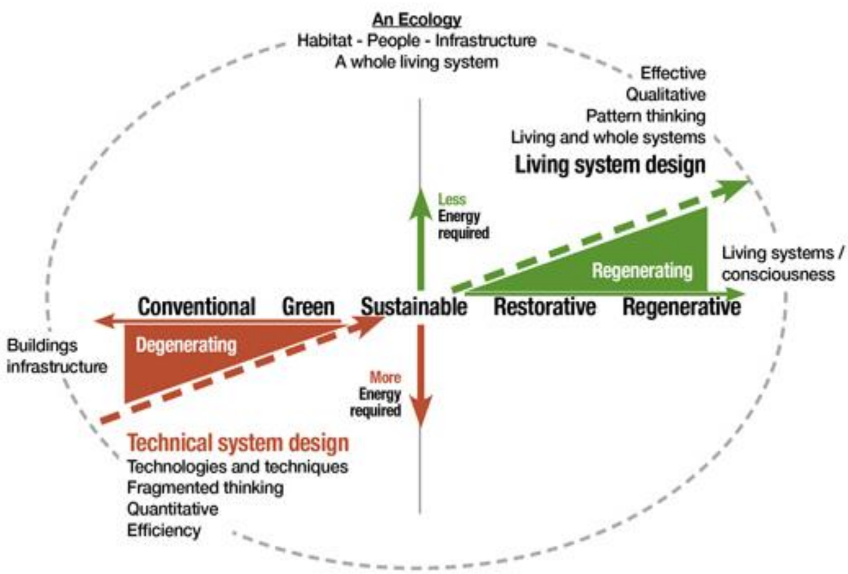

Fig.1.6: Trajectory of environmentally responsible design. [58]

[57] Plessis Chrisna du, "The City Sustainable, Resilient, Regenerative–a Rose by Any Other Name?" in Design for Regenerative Cities and Landscapes (Springer, 2022).

[58] Mang Pamela, "Regenerative Development and Design," in *Sustainable Built Environments*, ed. Reed Bill (2020), p 123.

The paradigm shift occurs when transition from a degenerative system with sustainability focused on fragmented, issue-based solutions to a regenerative system with a living systems approach, which improves completeness[59]. The environmental trajectory proceeds as follows: traditional legal practice; high-performance design, which improves efficiency and reduces negative impact; green building, which results in relative improvement working toward no harm; sustainability, which is viewed as a neutral position with net-zero effect; and then moving above the line to restorative approaches, which aim to restore healthy function in local natural systems[60]. Finally, a regenerative design considers humans as co-creators of nature and its co-evolutionary processes. Each phase might be regarded as a separate paradigm, with different goals and tactics representing other schools of thought. It is more than a clear hierarchy or linear progression because it tries to fix issues or limitations in existing paradigms[61].

1-9 Regenerative Design

The term "regenerative design" was coined to describe a philosophy that views all human activities and environmental systems in a broader context than the traditional idea of sustainability[62]. It fundamentally repositions human action, observe, and learn from the inherent wisdom in the natural world[63], as shown in figure (1.7). Regenerative practices expand beyond traditional design features to address a distinct thinking style and interactivity necessary to create and engage in a regenerative process[64]. The regenerative design incorporates diverse environmental, cultural, social, and economic systems. The regenerative design provides a better system that recognizes humans as a part of the ‘ecosystem’ and values the need for humans to be integrated

[59] Sylvia Coleman et al., "Rethinking Performance Gaps: A Regenerative Sustainability Approach to Built Environment Performance Assessment," *Sustainability* 10, no. 12 (2018).

[60]Zachary Jewison, "Regenerative Architecture: Making Nature an Equal Partner in Design" (North Dakota State University, 2019).

[61] Plessis Chrisna du, "The City Sustainable, Resilient, Regenerative–a Rose by Any Other Name?" in Design for Regenerative Cities and Landscapes (Springer, 2022).

[62] Leah V Gibbons, "Regenerative—the New Sustainable?," *Sustainability* 12, no. 13 (2020).

[63] Kimberly Camrass, "Regenerative Futures," *foresight* 22, no. 4 (2020).

[64] Pamela Mang and Bill Reed, *Regenerative Development and Design*, Sustainable Built Environments (2020).

into it[65]. The regenerative approach is considered the highest architectural design concept regarding positive productivity toward the environment.

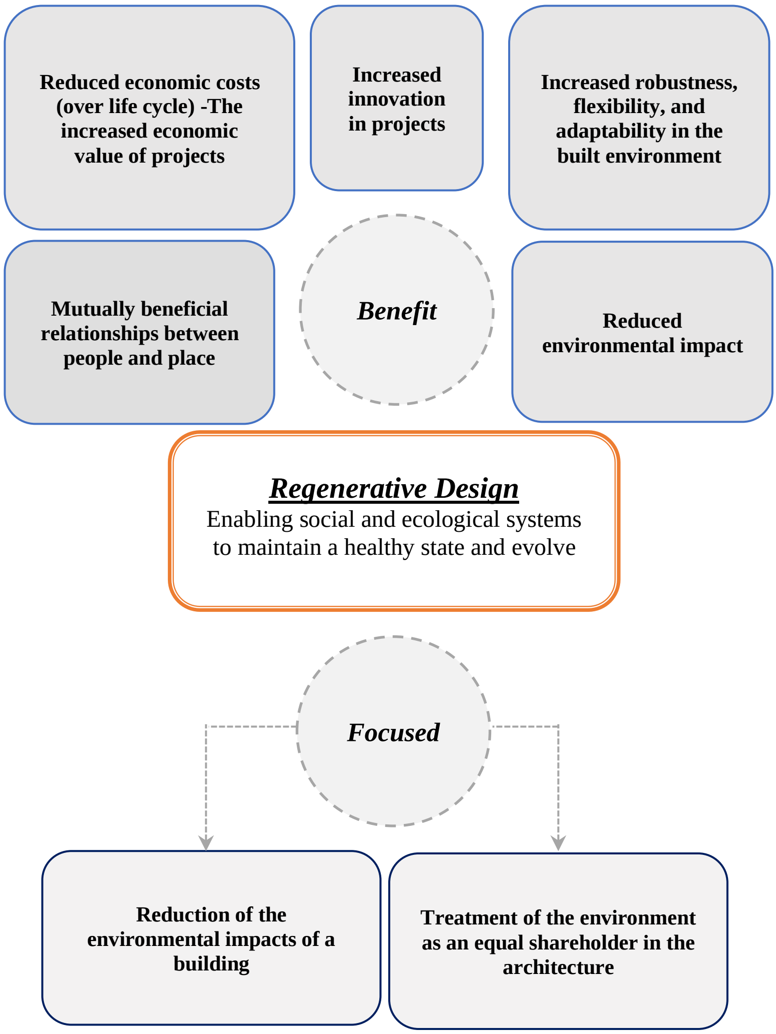

Fig.1.7: Overview of the regenerative design.[66]

Advocates are invited to incorporate eco-efficient design technologies and processes into an ecologically oriented plan to reverse the degradation of the natural and human systems on the planet and the

[65] Dominique Hes, "Designing for Hope," ed. Chrisna Du Plessis (Routledge, 2014).

[66] Aysegul Akturk, "Regenerative Design and Development for a Sustainable Future: Definitions and Tool Evaluation" (University of Minnesota, 2016).

human systems that inhabit them[67]. Three significant goals underpin regenerative design. To begin, it is to create the conditions for creating individual ecosystems that grow urban biodiversity and, thus, the city's ecological foundation, whether in ecosystems or neighborhoods[68].

However, it is not only about establishing an environmental foundation but also about more complex and diverse social and cultural systems. Second, it is about providing more than one took out, not just in terms of monetary or resource, but also in increasing and certifying the many soft elements of our human systems.Contribution activities that strengthen and enhance the many interactions and flows in which the social-ecological system functions as a node. The ultimate goal of regenerative design is to "create a connection" by reconnecting humans with the environment (as in ecosystems both inside and outside of them) and connecting individuals to their communities and communities of life to one another[69].

The main challenge of regenerative design is providing and considering the potential for ‘Renew,’ ‘Rebirth,’ and ‘Recover’ the previously rendered damages to human socio-economic respect and the environment[70]. Accordingly, the regeneration concept intends to further the generation consumption systems. Therefore, to be regenerative, a plan must provide the factors such as being sustainable for today and tomorrow and mending the previously caused damages to the economy, society, and environment.

1-9-1 Regenerative Design Importance

While regeneration procedures produce apparent results, it is vital to comprehend why required. Scholars have identified four critical explanations for the growing popularity of regenerative methods.

[67] Haritha Bharath, "A Study on Regenerative Architecture" (paper presented at the Conference proceedings of the National Institute of Technology, 2019).

[68] Attia Shady, Regenerative and Positive Impact Architecture: Learning from Case Studies (Springer, 2018).

[69] Du Plessis, "The City Sustainable, Resilient, Regenerative–a Rose by Any Other Name?."

[70] Sylvia Coleman et al., "Rethinking Performance Gaps: A Regenerative Sustainability Approach to Built Environment Performance Assessment," Sustainability 10, no. 12 (2018).

These include moving beyond 'doing less or no harm' approaches[71], the industry's push to achieve higher performance goals, a new paradigm due to the mechanistic worldview's inappropriate thinking processes, and a motivating positive discourse to address the problems[72]. The four reasons are as follows:

First, there is a need to move beyond 'doing little or no harm' to increase socio-ecological systems' health and vitality. Design professionals are advancing green building technology. However, more severe issues, such as climate change and biodiversity loss, must still be addressed. Current green and sustainable design approaches, on the other hand, outperform traditional design[73]. Regarding energy and resource conservation, waste reduction, material replacement, and quality of life. It seeks to create the least environmental and human health harm while utilizing less nonrenewable energy and producing less pollution[74].

Simultaneously, rather than simply slowing down the degradation (adverse consequences), it is necessary to reverse it. Regenerative design and development aim to go beyond eco-efficient design by transitioning from a 'net-zero' to a 'net-positive' approach to ecological, social, and economic development[75]. The goal of regenerative design and development is to promote human-nature co-evolution. It necessitates an understanding that human health depends on the health of entire ecosystems and vice versa[76].

Second, many architectural practitioners have gained experience in green design by developing buildings that achieve 'Platinum,' the

[71] Du Plessis Chrisna "Towards a Regenerative Paradigm for the Built Environment," in *Building Research & Information* (Building Research & Information, 2012).

[72] Leah V Gibbons, "Regenerative—the New Sustainable?," Sustainability 12, no. 13 (2020).

[73] Plessis Chrisna du, "The City Sustainable, Resilient, Regenerative–a Rose by Any Other Name?," in Design for Regenerative Cities and Landscapes (Springer, 2022).

[74] C. Trombetta and G. Cavanna, "Regenerative Design as a Contribution to Understanding Resilience to Climate Change," *Archistor-Architecture History Restoration*, no. 12 (2019).

[75] Mateusz Płoszaj-Mazurek, Elżbieta Ryńska, and Magdalena Grochulska-Salak, "Methods to Optimize Carbon Footprint of Buildings in Regenerative Architectural Design with the Use of Machine Learning, Convolutional Neural Network, and Parametric Design," *Energies* 13, no. 20 (2020).

[76] Mang, Pamela and Reed, Bill, "Regenerative Development and Design," Sustainable Built Environments (2020).

highest level of performance within the LEED program[77]. At the same time, as green building practice has matured, practitioners who have operated at this level have sought to go considerably further than the performance ambitions implicit in current assessment techniques. As a result, regenerative design provides a robust framework for defining future design approaches.

Third, regenerative approaches advocate shifting from a mechanistic to an ecological viewpoint in order to provide living systems thinking. The current sustainability paradigms have lost their utility because of their conceptual foundation in an unsuitable mechanistic worldview. The regenerative approach confirms the value of how see the world, how we define the problems to be solved, and how can contribute as designers.

Fourth, there is a need for positive broadcasts in society to inspire optimism in the face of dread, as the mainstream atmosphere and sustainability narrative emphasize scarcity and negative consequences. To overcome the challenges, it is necessary to manifest a good report and move away from current fear-based records[78].

1-9-2 Main Characteristics of Regenerative Design

Regenerative design and development advocates call to serve people's design and construction requirements, the earth, and living things. Furthermore, the regenerative approach emphasizes a co-creative partnership with nature based on adaptation, resilience, and regeneration techniques, providing an expressly intended option of engaging with a living environment. The nine key characteristics (philosophical departure points) of regenerative design were identified; the purpose of this section is to investigate what critical characteristics of regenerative approaches have been discovered in the literature, as illustrated in figure (1.8).

1-9-2-1 Shifting the Prevailing Paradigm

Regenerative design needs to shift the dominant paradigm from a mechanical to an ecological perspective. There is a need to adopt a new way of thinking about how buildings are planned, designed, built, and

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[77] Raymond J Cole et al., "A Regenerative Design Framework: Setting New Aspirations and Initiating New Discussions," *Building Research & Information* 40, no. 1 (2012).

[78] Aysegul Akturk, "Regenerative Design and Development for a Sustainable Future: Definitions and Tool Evaluation" (University of Minnesota, 2016) : p22.

operated, as well as the responsibilities of designers and residents, regarding a site as a network of interrelated dynamic activities. Furthermore, adopting whole living system thinking is one of the essential notions of an ecological worldview that necessitates behavioral modifications to understand the total system rather than its parts.

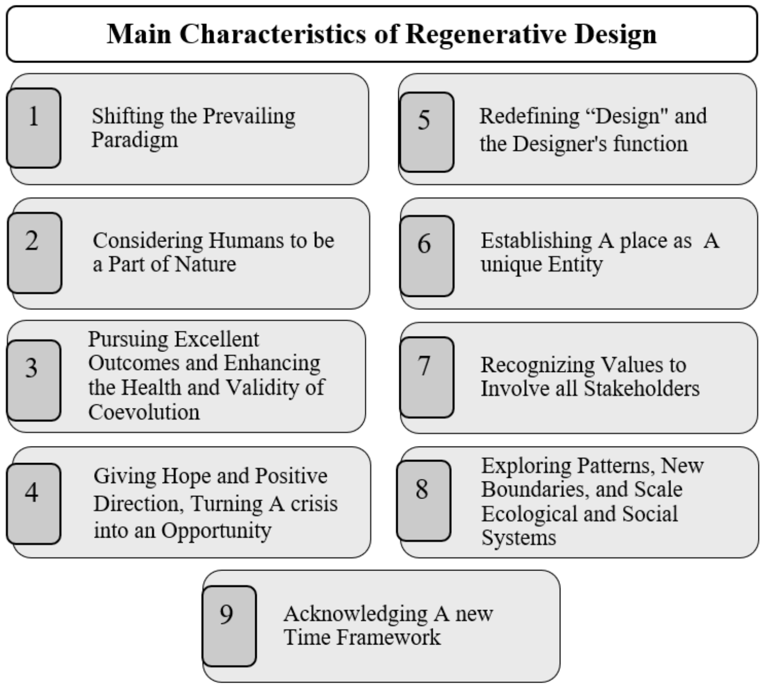

Fig.1.8: Summary of main characteristics of regenerative design. [79]

1-9-2-2 Considering Humans to be a Part of Nature

Co-evolution is a feature of living systems that are layered, dynamic, interconnected, and developing. The regenerative design addresses the dysfunctional human-nature relationship by collaborating with nature[80].The regenerative approach necessitates reconnecting human ambitions and actions with natural system evolution (co-evolution). The regenerative design recognizes humans as an intrinsic part of nature and positively impacts the plans. It explains how humans must progress in

[79] Emanuele Naboni and Lisanne Havinga, *Regenerative Design in Digital Practice. A Handbook for the Built Environment* (2019).

[80]Chrisna Du Plessis, "Towards a Regenerative Paradigm for the Built Environment," Building Research & Information 40, no. 1 (2012).

mutually beneficial and collaborative ways with nature. Furthermore, the goal is not simply to preserve an ecosystem but also to restore it. Instead, regeneration effort is defined by culture's ongoing progress in life development[81].

1-9-2-3 Pursuing Excellent Outcomes and Enhancing the Health and Validity of Coevolution

The regenerative approach proposes viewing the built environment as a catalyst for positive change, to improve the health and vitality of both communities on physical, psychological, social, and economic levels, as well as other living organisms and systems via development. It is necessary to produce and reinvest extra resources and energy in order to increase the capacity of the underlying linkages through supporting systems of a place required for community resilience and continued evolution[82].

1-9-2-4 Giving Hope and Positive Direction, Turning A crisis into an Opportunity

Because of rising environmental challenges, sustainability's current attitude and narrative emphasize alarm 'This frightening environment has a harmful psychological influence on people. Where this frightening atmosphere impacts people psychologically, and it could have little interest in maintaining tolerance and engagement. The regenerative design provides a constructive discourse to overcome challenges by encouraging collective effort to solve problems. A crisis may present an opportunity for rebirth and the emergence of new ideas[83].

1-9-2-5 Redefining "Design" and the Designer's Function

Enhancing life in all its forms, including humans, other animals, and ecological systems, is a problematic design aim that necessitates a unique design method. A regenerative practitioner should create an ecosystem encompassing natural and human life systems, necessitating an integrated design approach and a multidisciplinary workforce. The two supporting and underlying design techniques for regenerative design and development are integrated and ecological design.

[81] Pamela Mang and Bill Reed, "Regenerative Development and Design," Sustainable Built Environments (2020): p492.

[82] Mang, Pamela and Reed, Bill, "Regenerative Development and Design," Sustainable Built Environments (2020).p245.

[83] Hes Dominique, "Designing for Hope: Pathways to Regenerative Sustainability," ed. Chrisna Du Plessis (Routledge, 2014).

1-9-2-6 Establishing A place as A unique Entity

Place is accepted and promoted as the primary starting point for design in regenerative approaches. It highlights the concept of a place as a multi-layered network of living systems within a geographic region that comes from the intricate interactions of natural ecology (temperature, mineral and other deposits, soil, vegetation, water, and wildlife, among other things). Also, as cultural aspects (distinctive practices, expressions of beliefs, economic activities, modes of association, educational ideals, traditions, etc.[84] Every place has its history, culture, ecology, and economic tendencies. It is vital to comprehend these patterns, create for a given location, and refrain from utilizing template designs to reach regeneration.

1-9-2-7 Recognizing Values to Involve all Stakeholders

Recognizing place values to start a conversation is crucial and serves numerous purposes:

1- By allowing individuals to comprehend, share, learn, and adapt harmoniously with the environment.
2- Stories have the potential to be significant change agents.
3- Learning about a place's history gives insight into how people might better deal with biological systems for the greater good, facilitating coevolution by providing a continual learning process.
4- By telling the same tale (in a distinct location), all stakeholders are brought together and reminded of the importance of symbiotic connections. Where it boosts social-ecological interaction, allowing for even more regeneration and Design[85].

1-9-2-8 Exploring Patterns, New Boundaries, and Scale Ecological and Social Systems

A building is a system embedded in larger ecological and social systems on which it has an impact but is also impacted[86]. Regenerative

[84] Mang, Pamela and Reed, Bill, "Regenerative Development and Design," Sustainable Built Environments (2020): p492.

[85] Ibid: p493.

[86] Chrisna Du Plessis and Peter Brandon, "An Ecological Worldview as Basis for a Regenerative Sustainability Paradigm for the Built Environment," *Journal of Cleaner Production* 109 (2015): p 5.

development "cannot live in isolation from their wider surrounding contexts" and necessitates "a larger scale (city, region, ecosystem border) knowledge of ecosystem services[87]. Knowing limits and reading the landscape are working on giving the relational awareness necessary to build a constructed environment that harmonizes with and contributes to natural flows.

1-9-2-9 Acknowledging A new Time Framework

Uncertainty of time required for regeneration emergence is one of the issues faced by the regenerative design and development literature. Delivering final plans, approvals, and construction does not conclude regenerative design and development. Instead, the regenerative potential of a project might be sustained throughout time by integrating people who live and administer it if a culture of co-evolution is successfully established[88].

1-10 Regenerative Design Framework

The regenerative design should be integrated and holistic and redefine the concept of sustainability in designing the built environment[89]. The core objectives of the regenerative design, after conclusions from the literature, the detailed framework, shown in figure (1.9), is developed based on the four core objectives of regenerative design i.e., place, whole systems thinking, biological equity, and net positive impact[90].

This enables the practitioners to measure the actual impact of their project. The limitations inferred, which require awareness during the design process, are addressed in detail under the scope of the design. The final column quotes the practical techniques adopted, which proved successful and assisted the practitioners in the application process[91]. The framework developed is a process-based advocacy tool that can be utilized

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[87] Maibritt Pedersen Zari, "Ecosystem Services Analysis for the Design of Regenerative Built Environments," *Building Research & Information* 40, no. 1 (2012): p 62.

[88] Mang, Pamela and Reed, Bill, "Regenerative Development and Design," Sustainable Built Environments (2020): p498.

[89] A Charanya Devi and J Jeyaradha, "The New Green Regenerative Architecture" (paper presented at the IOP Conference Series: Earth and Environmental Science, 2023).

[90] Ibid.

[91] Ibid.

in the design as agreeably as the evaluation of the existing proposals using the fourth core objective i.e., net positive impact.

The first three columns in strategies are present the categories and design scope, which assist in the design process. The final column (techniques) can be allocated to the techniques inferred from new prototypes/techniques to be adopted.

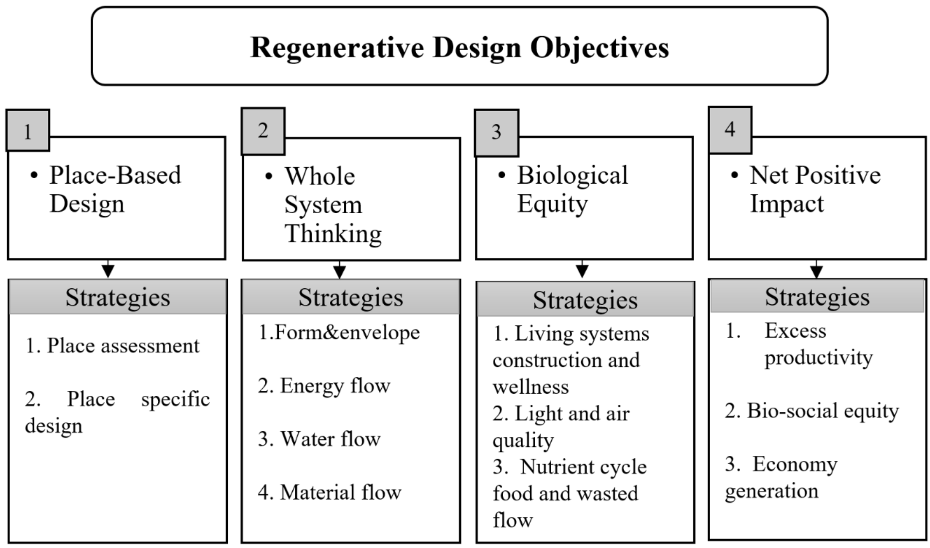

Fig.1.9. The four main objectives of regenerative design. [92]

1-11 Support Tools for Regenerative Design

Regenerative design and development are a new field working to treat the current sustainability paradigm. At the same time, the practitioners have already known that limiting the adverse effects of human interventions on nature is no longer sufficient[93].

Experts are developing new design and construction support tools and technological solutions to implement regenerative design principles to support this change toward a regenerative worldview. Based on the above-listed criterion, five of the most popular and widespread rating tools in the

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[92] Ibid.

[93] Attia Shady, Regenerative and Positive Impact Architecture: Learning from Case Studies (Springer, 2018).

construction industry were selected: LEED, BREEAM, DGNB, WELL, and Living Building Challenge (LBC)[94].

Where these tools emerge to depict critical characteristics and attributes and assist practitioners, designers, and stakeholders, emerging design support tools bridge the regenerative design and development theory to simplify the theoretical underpinnings and process. However, the change in current practice can take time and effort, so it is essential to have a tool or guide and metrics/indicators to understand and apply regenerative approaches. Therefore, the comparison explores the tools and the most influential indicator stations to determine existing gaps and recommendations for evolution toward the renewal goals (Appendix).

The thesis discusses the tools individually, the definition of each tool, where and when they were first published, and the requirements scale required for building. The "Rethinking Sustainability Towards a Regenerative Economy" book was used as a reference in comparing tools for choosing the suitable tool for supporting the aim of the thesis (Appendix). The final comparison result showed that the LBC tool covers all categories equally.

1-12 Overview of Living Building Challenge (LBC)

The Cascadia Green Building Council developed the Living Building Challenge (LBC) in 2006 and has been maintained by the International Living Future Institute (ILFI) since 2011. The LBC aims to promote fundamental systemic reform of the construction industry and its products, transforming them into sustainable and even regenerative systems (repairing the damage caused by previous unsustainable practices)[95]. In 2015, International Living Future Institute (ILFI) launched the Living Community Challenge (LCC), which aims to apply the LBC's concepts to whole communities[96].

In addition, the Living Product Challenge (LPC) was also recently developed to revolutionize consumer product production. The Living Building Challenge is divided into seven performance categories, or "Petals": Place, Water, Energy, Health + Happiness, Materials, Equity, and

[94] Sylvia Coleman et al., "Rethinking Performance Gaps: A Regenerative Sustainability Approach to Built Environment Performance Assessment," Sustainability 10, no. 12 (2018).

[95] Ali Sayigh, *Green Buildings and Renewable Energy: Med Green Forum 2019-Part of World Renewable Energy Congress and Network* (Springer Nature, 2019), p 129.

[96] Ibid.

Beauty. Each Petal is broken into Imperatives, giving the Challenge twenty Imperatives. As demonstrated in Table (1.1), the Imperatives can be applied to practically every imaginable building project of any scale and location, whether a new or existing one.

Table.1.1: Living Building Challenge categories (petals) and requirements. [97]

CATEGORIES	IMPERATIVES
PLACE	01. LIMITS TO GROWTH
	02. URBAN AGRICULTURE
	03. HABITAT EXCHANGE
	04. HUMAN-POWERED LIVING
WATER	05. NET POSITIVE WATER
ENERGY	06. NET POSITIVE ENERGY
HEALTH & HAPPINESS	07. CIVILIZED ENVIRONMENT
	08. HEALTHY NEIGHBORHOOD DESIGN
	09. BIOPHILIC ENVIRONMENT
	10. RESILIENT COMMUNITY CONNECTIONS
MATERIALS	11. LIVING MATERIALS PLAN
	12. EMBODIED CARBON FOOTPRINT
	13. NET POSITIVE WASTE
EQUITY	14. HUMAN SCALE + HUMANE PLACES
	15. UNIVERSAL ACCESS TO NATURE & PLACE
	16. UNIVERSAL ACCESS TO COMMUNITY SERVICES
	17. EQUITABLE INVESTMENT
	18. JUST ORGANIZATIONS
BEAUTY	19. BEAUTY + SPIRIT
	20. INSPIRATION + EDUCATION

A project can receive Petal Certification by meeting the requirements for three of the seven Petals, at least one of which must be energy, water, or materials. The IBC emphasizes the significance of

[97] International Living Future Institute, "Living Building Challengesm 4.0 a Visionary Path to a Regenerative Future," (LIVING BUILDING CHALLENGE, 2019).

context, and each Imperative and Petal takes growth density and climate into account.

As a result, specific requirements are better addressed at the neighborhood or community level rather than the building level. Before a project can be certified, it must have a full year of operating experience and data to demonstrate compliance with the Imperatives[98]. The Living Building Challenge bridges the gap between ancient and contemporary worldviews in an intriguing way. Using the tools of the mechanistic worldview to draw customers and project teams further into a better knowledge of a project's interactions with its Place may assist them in changing toward an ecological worldview very imperceptibly.

As proven by the diverse range of projects presently underway in many countries, Living Building Challenge projects can be created in any climate zone anywhere on the planet. The Living Building Challenge connects the old and new worldviews by drawing customers and project teams into a deeper awareness of a project's relationships with its Place, allowing them to transition imperceptibly towards an ecological worldview[99]. It provides a much more strict 'checklist' than any of the Green Building grading schemes in some ways, but it also allows for much more flexibility in meeting those requirements. The program's merit is that it provides a vision as well as particular limits but does not prescribe a process[100].

1-13 Living Building Challenge Certifications

LBC is a holistic benchmark that requires projects to strive for perfection across all seven Petals. As a result, LBC certification methods require evaluation of all the Petals mentioned in this standard figure (1.10).

1-13-1 Living Certification

The certification is intended for projects targeting the highest level of sustainability and regenerative design. Living Certification is obtained by completing all of the Imperatives assigned to a project's Typology. New

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[98] Sayigh, *Green Buildings and Renewable Energy: Med Green Forum 2019-Part of World Renewable Energy Congress and Network*, p 130.

[99] Raymond J. Cole, "Regenerative Design and Development: Current Theory and Practice," Building Research & Information 40, no. 1 (2012).

[100] LBC "Living Building Challenge 4.0 : A Visionary Path to a Regenerative Future," (International Living Future InstituteSM, 2019).

Buildings should meet all twenty Imperatives, whereas other typologies must meet similar but scope-dependent criteria figure (1.10)[101].

1-13-2 Petal Certification

The certificate is designed for projects that desire to concentrate on a single issue or Petal of the Living Building Challenge. This certification requires to complete all Core Imperatives as well as all Imperatives in the Water, Energy, or Materials Petals figure(1.10)[102].

1-13-3 Core Green Building Certification

The certification is designed for initiatives seeking a high-aspiration certification that is verifiable, holistic, and easily achieved. Projects must meet the requirements of all ten Core Imperatives, as well as up to two Core Imperatives each Petal, and must demonstrate water and energy performance over a twelve-month period. This Standard condenses all of the Imperatives required for this certification into the Core Green Building Certification Standard figure (1.10)[103].

1-13-4 Zero Energy Certification

Initiatives that aim to attain net zero energy through on-site renewable energy generation are certified. Net zero energy has been defined in a variety of ways by the market, however, ILFI has a definite definition: The building's net annual energy requirements should be satisfied entirely by on-site renewable energy, with no combustion figure (1.10)[104].

1-13-5 Zero Carbon Certification

A certificate is awarded to projects that have an impact on climate change through the use of energy and materials. This accreditation requires that all active energy demand associated with the project be offset by new on- or off-site renewable energy. It also necessitates a specific level of energy efficiency and a reduction in the project's essential components' displayed carbon. In addition, 100% of the carbon emissions effects linked with the project's construction and materials should be informed and offset

[101] LBC, "3.0: A Visionary Path to a Regenerative Future," (International Living Future InstituteSM (International Living Future …, 2017).

[102] International Living Future Institute, "Living Building Challenge sm 4.0 a Visionary Path to a Regenerative Future," (LIVING BUILDING CHALLENGE, 2019).

[103] Ibid.

[104] Ibid.

for additional information on membership, registration, and certification figure (1.10)[105].

1-14 Conclusion of Chapter One

This chapter introduced the main concepts regarding creating an environmentally responsible future. It includes climate change and its causes and impacts, how to face the changes, and the idea of regenerative design and its imports, impacts, and main characters. Also, it discussed the support tools of regenerative design and development. This chapter reaches the following conclusion:

1- The concept of regenerative design offers the promise that buildings can "add value" by being planned and operated to generate more than required to meet their needs, and the net-positive energy system is one of the main core principles of regenerative design.

2- The Living Building Challenge contains seven petals, but we will specialize in the energy petal. "Energy Petal" plans to achieve net-positive energy and develop new renewable energy sources that enable projects to function robustly, and carbon-freely.

[105] Ibid.

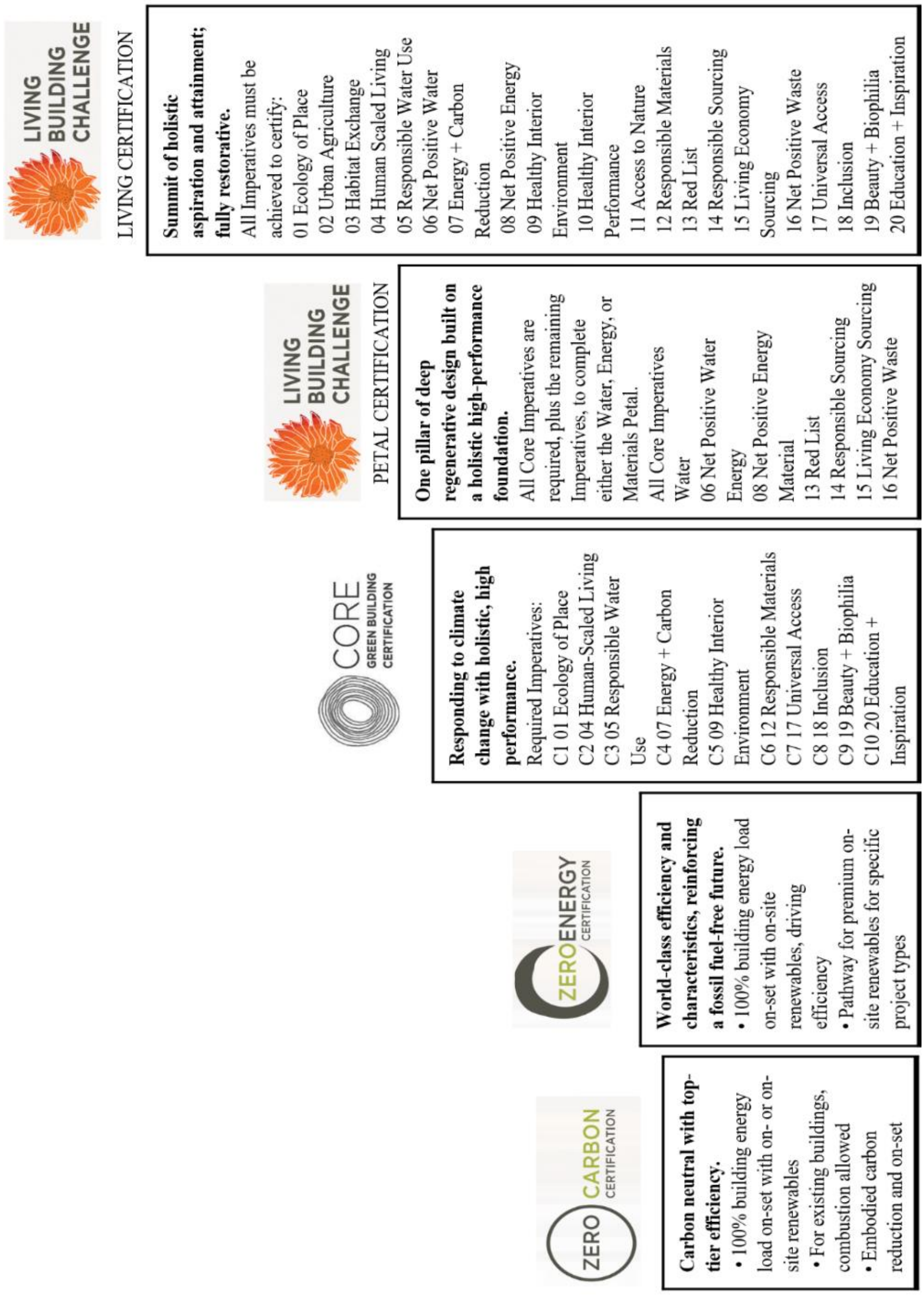

Fig.1.10: Living Building Challenge certification. [106]

[106] Ibid.

CHAPTER TWO

Net-Positive Energy System for Office Buildings

2-1 Introduction

Climate change is the most critical global challenge the world is facing today. To relieve climate change, there is a need to dramatically reduce emissions associated with human activities, primarily caused by energy production. The first step is to reduce energy use by improving the energy efficiency of operations. Building-integrated solar photovoltaic, heat pumps, and biofuels, among other technologies, might provide an essential portion of the energy in a renewable energy ecosystem. As a result, buildings may play a critical role in enabling the energy transition and reducing climate change. Positive energy buildings, known as Net-Positive Energy Buildings (NPEBs), will be required to reduce climate change.

Regenerative design focuses on reducing human activities' environmental footprint and creating net positive environmental impacts, Net-positive energy is one of the main core principles of regenerative design. Net-positive energy buildings are buildings that produce more energy than they consume; this includes fuel for heating, cooling, ventilation, lighting, and all plugged-in devices. They are meant to cut emissions from energy networks and systems. This chapter introduces the net-positive energy system definition, its framework, and how the system could be applied in the office building in Cairo.

2-2 Egyptian Office Building Characteristics

Between 2005 and 2021, Egypt's energy usage increased by 52%. While most current structures in Egypt are residential, commercial (such as office buildings and malls), or governmental, the most critical non-residential buildings are office buildings, which are increasing dramatically due to Egypt's rapid expansion. In contrast, it was observed in new business zones such as New Cairo. The modern definition of office buildings is facilities in which users of a particular organization or employees perform organizational or administrative work to support the work of this organization or corporation[1].

As a result, office buildings' primary function is to offer employees a working environment. The office building design has gone through many global influences that have reshaped its concept. These

[1] Lamiaa Abdallah and Tarek El-Shennawy, "Evaluation of Co2 Emission from Egypt’s Future Power Plants," *Euro-Mediterranean Journal for Environmental Integration* 5, no. 3 (2020).

influences greatly impacted office buildings, resulting in new design standards for architectural designs, building envelopes, safety and security, mechanical and natural lighting/ventilation integration, building materials, structural design, modules, and site selection. Nowadays, most office building designs adhere to outstanding architectural or environmental requirements to boost staff productivity and the organization's reputation in general office building design standards[2].

Therefore, the target of the thesis explained later is mainly aimed at improving the energy efficiency of office buildings to decrease fossil energy consumption, considering the source of pollution in Egypt and the apparent threat to the ecosystem[3].

2-3 Improve Buildings Performance

Efficient building technologies and equipment can be developed one step further to attain Net-Positive Energy Buildings (NPEBs) by progressing from Net-Zero Energy Buildings (NZEBs). When an NPEB generates more energy than it consumes, it helps to reduce Green House Gas (GHG) emissions in the surrounding energy system. In this regard, NPEBs are essential in decarbonizing the building sector[4]. In particular, a flexible energy asset should help lower energy system congestion. Buildings and energy communities can now exchange energy (thermal, electrical, or other future energy carriers) with the grid or each other, acting as integrated components of the energy system. In the following sections, will go through Net-Positive Energy in depth.

2-4 Energy Situation of Egyptian Office Buildings

The energy grid will supply electricity to highly efficient structures that do not contribute to the negative externalities of combustion or fission. Despite significant progress in the cost-effectiveness and performance of renewable energy sources, many projects still rely on fossil fuel infrastructure due to financial or regulatory constraints. The production and, in particular, the usage of natural gas (NG) and crude oil continue to be the dominant energy supply and GHG emission sources in the energy sector value chain. Despite Egypt's Integrated Sustainable Energy Strategy

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[2] M Hamza, S Alsaadani, and M Fahmy, "Exploring the Potential of Nearly Zero Energy Retrofitting for Generic Office Buildings in Cairo, Egypt," *Energy Reports* 8 (2022).

[3] Ahmed Shahin and D Sumiyoshi, "Building Energy Simulation Towards Developing a Guideline for Nzebs in Egypt," *Department of Architecture* (2018).

[4] Rita Lavikka et al., *Positive Energy Buildings* (Springer, 2022).

ISES 2035's ambitious aims for integrating renewable energy and implementing energy efficiency measures, NG and oil together accounted for over 92% of total primary energy production in 2019[5].Natural gas and petroleum products met 98% of total primary energy demand in FY 2014/2015, compared to 1.5% from hydropower and 0.4% from coal. Furthermore, 0.1% of wind and solar energy 70 Egypt's significant surplus of potential power generating capacity of 21 GW in 2022 is still heavily reliant on thermal plants (90% of installed capacity). Educational, wholesale, retail, and office buildings have the most significant proportion of non-residential floor spaces (29%, 22%, and 17%, respectively; as shown in figure (2.1). In recent years, the annual pace of new residential development has ranged between 2% and 2.5%[6].

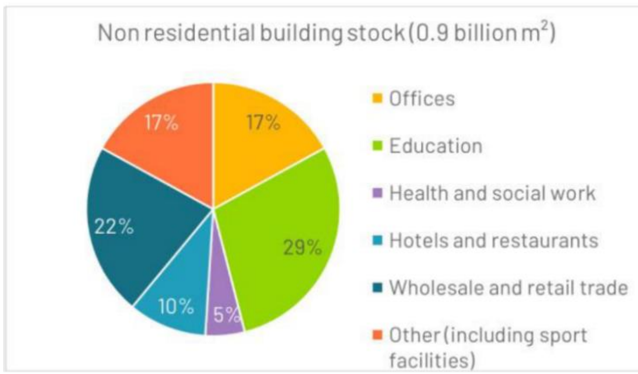

Fig.2.1 Building stock in Egypt in 2022. [7]

Net-Positive Energy Buildings should have deep knowledge of the driving factors determining occupant behavior for energy savings, comfort optimization, and respect for environmental resources. Energy consumption in office buildings is mainly due to a twofold contribution: consumption caused by work equipment and that which assures a healthy and comfortable internal environment for the occupants. It is recognized that occupants play a key role in the energy use of office buildings, and it is often perceived as one of the major causes of underperforming buildings. Considering the multi-parametric nature of comfort, it is necessary to examine the acceptable level of all the environmental conditions (thermal,

[5] Ahmed A. Hassan, "Cooling Sector Status Report Egypt: Analysis of the Current Market Structure, Trends, and Insights on the Refrigeration and Air Conditioning Sector," ed. Norhan El Dallal (Berlin, Germany: Guidehouse Germany GmbH Albrechtstr., 2022).

[6] Ibid.

[7] Ibid.

visual, and auditory comfort, as well as air quality), as shown in Figure (2.2). Whereas it was found that office buildings are influenced by several personal, social, and building factors, the perceived comfort is much greater than the average of perceived indoor air quality, noise, lighting, and thermal comfort responses.

1 COMFORT AND SATISFACTION
- Thermal
- Visual
- Acoustic
- Air quality

2 CONTROL AND ACTIONS
- Decision on the devices control
- Shared control
- Perceived productivity

3 WORKSPACE
- Building (envelope and year of construction)
- Office (private, shared, cubicle, …)

4 BEHAVIOR
- Windows opening/closing
- Blinds opening/ closing
- Thermostat setting
- Lighting usage

5 DEMOGRAPHICS
- Work position
- Hours of work
- Age
- Gender
- Nationality
- Level of education

Fig.2.2. Occupant actions and activities influencing energy consumption in office buildings . [8]

2-5 Role of EGYPT for Reducing Energy

Egypt Vision 2030 aims to conserve 25% of current usage, which urges developing energy efficiency codes as a critical first step[9].Furthermore, adopting regenerative design concepts in existing structures may allow for more significant building code application, resulting in higher energy efficiency standards throughout the Egyptian building stock, even though Egypt does not currently have a net-positive criterion. The Egyptian government has taken steps to encourage sustainable and integrated energy plans by authorizing electricity generation from renewable energy sources. According to the New & Renewable Energy Authority, Egypt aspires to produce 20% of its energy from renewable sources by 2022, potentially tripling this by 2035. According to the most recent Egyptian census estimate, there are around 16.2 million buildings in Egypt (2017), of which approximately 0.8 million

[8] Marilena De Simone and Gianmarco Fajilla, "Occupant Behavior: A "New" Factor in Energy Performance of Buildings -Methods for Its Detection in Houses and in Offices," *Journal of World Architecture* 2 (2019).

[9] M Hamza, S Alsaadani, and M Fahmy, "Exploring the Potential of Nearly Zero Energy Retrofitting for Generic Office Buildings in Cairo, Egypt," Energy Reports 8 (2022).p116.

are office buildings.[10]. As a result, this study investigates the possibility of obtaining (net-positive energy) levels by retrofitting existing office buildings in Cairo, Egypt. It is expected that NPEB solutions could help to reduce CO2 emissions.

2-6 Definition of Net-Positive Energy Building

Net-Positive Energy Building (NPEB) is a new concept utilized to combat climate change, improve energy efficiency, and increase the use of renewable energy in buildings. NPEBs are buildings that produce more energy than they consume; this includes fuel for heating, cooling, ventilation, lighting, and all plugged-in devices as shown in figure(2.3). They are meant to cut emissions from energy networks and systems[11].

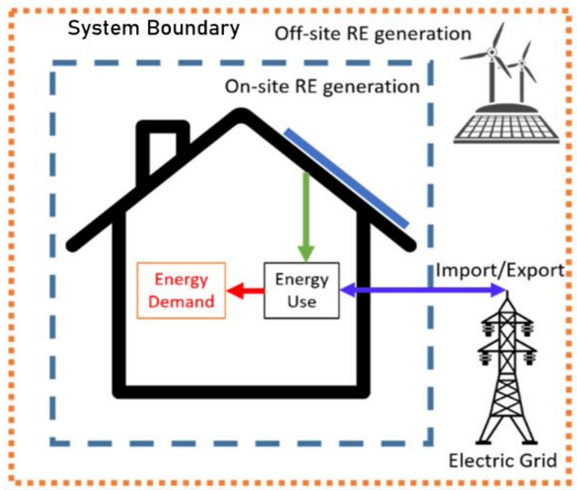

Fig.2.3: A brief outline of the net-positive energy building. [12]

The most straightforward concept on NPEB building is that it produces more energy on-site than it uses annually. That means the annual electrical energy surplus fed into the grid exceeds the annual power

[10] CAPMAS, "Central Agency for Public Mobilization and Statistics (Capmas) 2020.," (Http://www.capmas.gov.eg, 2020).

[11] Zahra S Hosseini and Raymond J Cole, "Lessons from Net Positive Energy to Be Applied in Net Positive Material Flows" (paper presented at the CaGBC National Conference & Expo, Vancouver BC, 2013).

[12] Gokula Manikandan Senthil Kumar and Sunliang Cao, "State-of-the-Art Review of Positive Energy Building and Community Systems," *Energies* 14, no. 16 (2021).

imported[13]. When considering a building's function, Net-Positive Energy adds value to its system in which it takes part rather than merely generating more imported energy versus its importation to the particular grid or buildings. In a system-based approach, the emphasis turns to maximizing energy performance. Net-Positive Energy Building (NPEB) approaches raise many new technical, behavioral, policy, and regulatory concerns and opportunities not seen in Net-Zero Energy Buildings (NZEBs)[14].

2-6-1 The similarity between net zero and net positive

Net-zero and net-positive goals necessitate similar actions, such as reduced energy use to compensate for energy produced on-site with renewable energy. In this respect, both buildings are high-performance and require a complete and integrated design approach. The second thing that Net-Zero and Net-Positive buildings have in common is that the evaluation is based only on current energy usage, regardless of building size or purpose. Finally, the assessment and calculation method for different types of buildings is the same as the hospital building will be evaluated similarly to a commercial office building[15].

2-6-2Challenges for Net-Positive building

According to a Scopus search, "Zero Energy Building" was used 2988 times, while less than 70 times were used for "positive energy building" until August 2021[16]. The thesis suggests a structured definition and framework for NPEB that might serve as a foundation for constructing such structures in African climate zones. The challenge in evaluating Net-Positive Energy Buildings based on a Net-Zero structure is that the Net-Positive Buildings goal goes beyond energy conservation as shown in Figure (2.4).

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[13] Abed Al Waheed Hawila et al., "Plus Energy Building: Operational Definition and Assessment," *Energy and Buildings* (2022): p 4.

[14] Raymond J Cole, "Net-Zero and Net-Positive Design: A Question of Value," (Taylor & Francis, 2015), p 5.

[15] Ming Hu, "Net-Positive Building and Alternative Energy in an Institutional Environment," *Summer Study on Energy Efficiency in Buildings; ACEEE: Pacific Grove, CA, USA* (2016): p 2.

[16] Mia Ala-Juusela et al., "Positive Energy Building Definition with the Framework, Elements and Challenges of the Concept," *Energies* 14, no. 19 (2021).

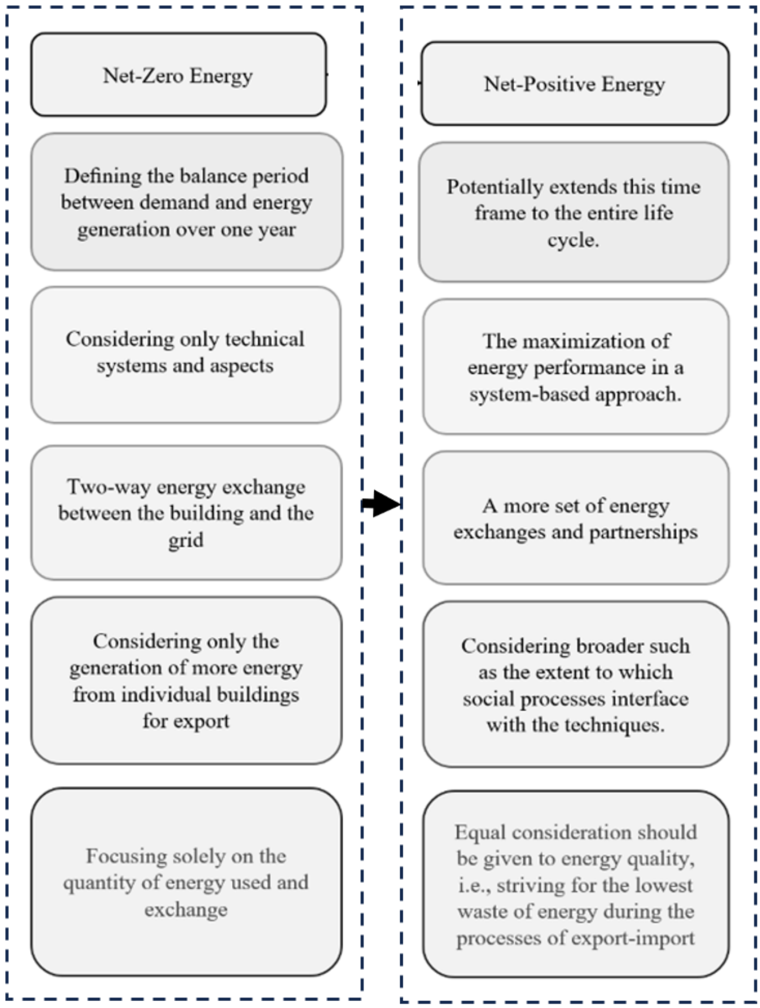

Fig.2.4: The shifting from net-zero energy to net-positive energy. [17]

Net-positive energy buildings contributing renewable energy to the surrounding environment, helping to reduce the carbon footprint of neighboring buildings This means more interaction with the energy grids than in the case of Zero-Energy Buildings[18]. The Net-Positive Building's goal is to investigate the possibilities of creating value for users and inhabitants. Increased productivity, tenant well-being, and energy savings

[17] Raymond J Cole and Laura Fedoruk, "Shifting from Net-Zero to Net-Positive Energy Buildings," *Building Research & Information* 43, no. 1 (2015).

[18] Mia Ala-Juusela et al., "Workshop on Positive Energy Buildings—Definition," *Environmental Sciences Proceedings* 11, no. 1 (2021): p 2.

beyond the specific building's border to add value[19]. The emphasis now changes to maximizing energy performance in a system-based approach rather than just comparing the generation of more exported energy versus its importation to different buildings or the grid[20].

2-7 Regenerative Design & Net-Positive Energy

The concept of regenerative design offers the promise that buildings can "add value" by being planned and operated to generate more than required to meet their needs, which is also the goal of NPEB. The Net-Positive design is not simply developing more energy but determining the purpose and designing how the excess resources could be deployed[21].

The idea of Net-Positive Energy is “physical development that achieves Net-Positive impacts during its life-cycle over pre-development conditions by increasing economic, social, and ecological capital[22]. Net-Positive Energy can be said to be a core principle of regenerative design. While Net-Positive Energy buildings adhere to many of the same criteria as Net-Zero Energy buildings, the concept of Net-Positive Energy buildings brings some new needs and possibilities.

2-8 Framework for Net-Positive Energy

A technical framework is required to serve as the foundation for an NPEB and the criteria would vary depending on location, climate, and municipal restrictions. As a result, when developing an NPEB, it is critical to consider local variables, which vary depending on weather and building codes. Figure (2.7) depicts a schematic diagram of the NPEB concept, encompassing the technological Framework, building boundary, principal components, the interaction between elements and grids, and energy flows[23].

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[19] Lavikka et al., *Positive Energy Buildings*.

[20] DEKD Kolokotsa et al., "A Roadmap Towards Intelligent Net Zero-and Positive-Energy Buildings," *Solar energy* 85, no. 12 (2011).

[21]Raymond J. Cole, "Regenerative Design and Development: Current Theory and Practice," Building Research & Information 40, no. 1 (2012).

[22] Ibid.

[23] Rita Lavikka et al., Positive Energy Buildings (Springer, 2022): p16.

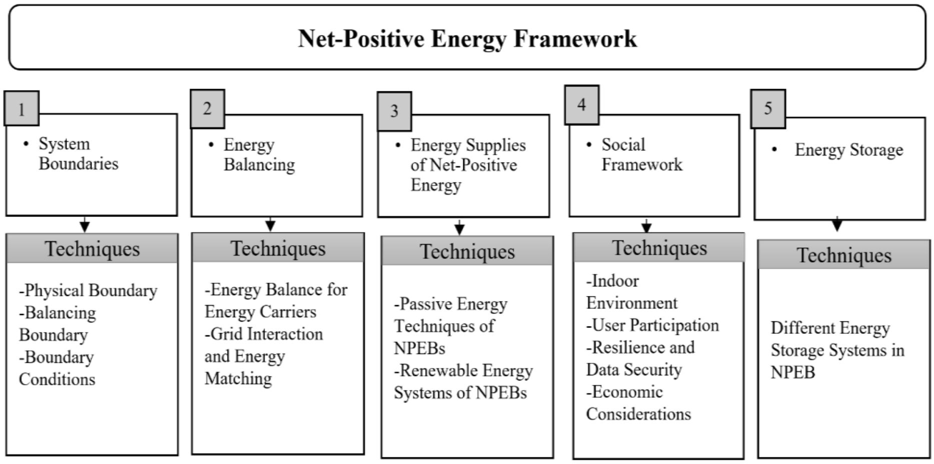

Fig.2.5: Summery of net-positive energy framework. [24]

2-8-1 System Boundaries for NPEB

The NPEB system boundary should specify the region suitable for renewable energy installations and the sort of energy that flows across the border. There are two types of limitations: physical boundary and energy balance boundary. Heating, cooling, and electricity are common types of energy that travel across the edge. The energy flow estimation consists of the plug loads, HVAC, lighting, and water heating. In addition to electric vehicles or water treatment. Measuring and considering these loads is essential to offer better control of NPEBs.[25]

2-8-1-1 Physical Boundary

The building's physical boundary as a Net-zero energy building system refers to its geographic periphery, where it is situated, and where the energy system is physically built. It determines if renewable resources are 'on-site' or off-site, and it is required to determine whether 'onsite' generation exists and whether renewable sources and storage are located within or outside the boundary. If the energy source comes from somewhere other than the site, it is considered imported energy, which impacts the primary energy variables.

The energy exchange on an open grid or two grids would allow the building to receive energy when needed, and the grids might carry

[24] Author.

[25] Mia Ala-Juusela et al., "Positive Energy Building Definition with the Framework, Elements and Challenges of the Concept," Energies 14, no. 19 (2021).

heating, cooling, electricity, gas, or water. Net-Positive Energy Building (NPEB) is a new concept utilized to combat climate change, improve energy efficiency, and increase the use of renewable energy in buildings. This extra energy could be stored on-site or sold to the grid beyond the perimeter.

2-8-1-2 Balancing Boundary

The balancing boundary is the limit across which the energy carrier under consideration is balanced, and it is required to identify the energy types employed and evaluated in NPEB buildings. Would encompass heating, cooling, electricity, and fuel, whereas operational power includes electricity, heating, cooling, ventilation, domestic hot water, fixed lighting, and plug loads[26].

2-8-1-3 Boundary Conditions

The first stage is to determine the building's purpose and function, space use, temperature condition, and comfort level. The space used determines how space is divided among users. The space use might be specified in terms of people per square meter or energy use per person. In addition to the usage of space, the use schedule is critical. The purpose and plan of the building can guide the people's density and the amount of peak hour or peak demand that can arise. The energy demand might be affected by scheduling changes. Furthermore, the climatic conditions must be identified[27].

2-8-2 Energy Balancing

Energy balancing is the process of balancing supply and demand over a year, month, or hour. In general, the weighting factor determines how different energy carriers are transformed into primary energy. The weighting variables turn the different energy carriers into comparable measures. This idea is utilized in net-zero energy buildings such that the weighted supply meets or may exceed the weighted demand over a year. The balance is calculated as follows:

Equation 1: Net-Zero Energy Building balance:

$$\text{NZEB balance: } |\text{weighted supply}| - |\text{weighted demand}| = 0$$

[26] Zahra S Hosseini and Raymond J Cole, "Lessons from Net Positive Energy to Be Applied in Net Positive Material Flows" (paper presented at the CaGBC National Conference & Expo, Vancouver BC, 2013).

[27] Rita Lavikka et al., Positive Energy Buildings (Springer, 2022).

Figure(2.6) depicts the concept of Net-Zero Energy Building and the placement of the terms discussed above in the Net-Zero Energy Building concept definition.

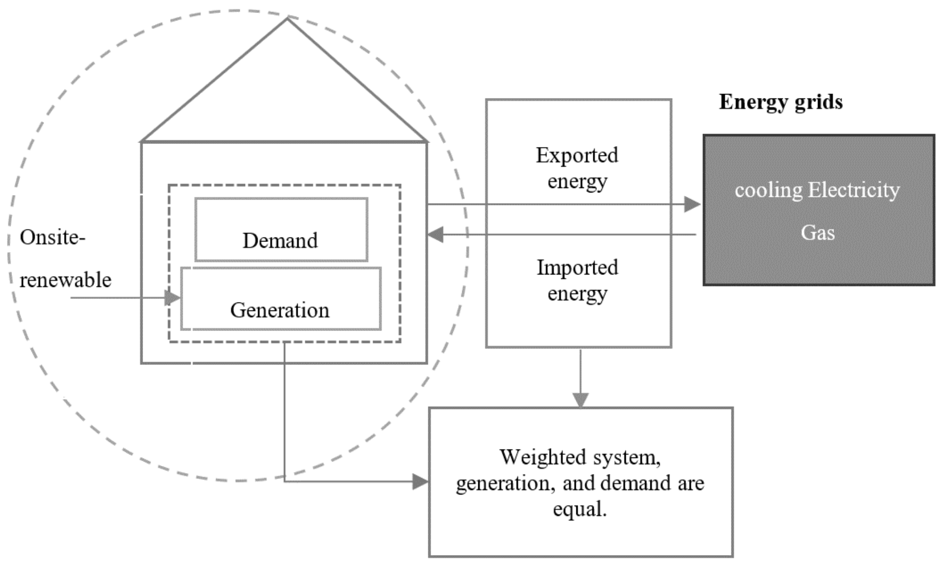

Fig.2.6: Net-positive energy building core concept and definition. [28]

This idea might be the basis for an NPEB report. Each energy carrier is measured in kWh, kWh/m2 for heating, cooling, and electricity, and MMBtu (Metric Million British Thermal Unit) for gas[29]. To be considered a Net-Positive Energy Building (NPEB), the energy export should be greater than the power import.

2-8-2-1 Energy Balance for Energy Carriers

The weighting variables translate the various energy carriers into comparable measurements, allowing for easier comparison of the effects. This can include things like main energy or emissions. Each energy carrier's energy flow in the NPEB is most frequently balanced using direct energy. Many other balancing methods can be used, such as balancing the year's supply and demand or importing and exporting power to and from the grid. Each technique has specific benefits and drawbacks[30]. For

[28] Rita Lavikka et al., Positive Energy Buildings (Springer, 2022).
[29] Ibid, p 31.
[30] Zahra S Hosseini and Raymond J Cole, "Lessons from Net Positive Energy to Be Applied in Net Positive Material Flows" (paper presented at the CaGBC National Conference & Expo, Vancouver BC, 2013), p26.

instance, the load and generation calculation are easier to apply and, therefore, widely used. It could be measured by estimating or measuring the building's total annual demand and total annual generation onsite from renewable sources. This strategy, however, may not provide the grid exchange. The second method is more thorough, calculating energy input and export via a grid. It depicts the interplay of the grid. It is, however, difficult to get because it could include hourly data on energy consumption, generation, export, and import for each energy carrier.

2-8-2-2 Grid Interaction and Energy Matching

The energy grid is the channel or medium via which energy, heating, cooling, gas, or fuel passes when it comes to energy matching and grid interaction. The grid can be either one-way or two-way. One approach is to deliver energy to the building solely from the national grid or another source. The two-way (or bi-directional) grid is the path that provides electricity to the building while also receiving power from the building. Because the NPEB is, it could be integrated with the bidirectional grid and have the option of sharing energy with the neighborhood.[31]

Another critical issue to solve is whether renewable energy supply could be exported to the neighborhood or if renewable energy supply may be used on-site to minimize demand for the building. Renewable energy should meet the yearly energy balance in NPEB, which is the difference between demand and supply. The external grid or local storage should fill the short-term hourly mismatch. When aiming for high self-sufficiency or matching, the emphasis should be on onsite storage to offset the short-term mismatch; grid energy can then fill in the gaps.

2-8-3 Energy Supplies of Net-Positive Energy

Net-Positive Energy Buildings need to energy supply through the following:

2-8-3-1 Passive Energy Techniques of NPEBs

To satisfy demand, Net-Positive Energy Building emphasizes reduced energy consumption, increased energy efficiency, and leftover energy generation. The supply, direction, and balance of an NPEB are compared to those of a NZEB and a traditional structure. Despite this, NPEB status could be obtained by reducing usage and increasing energy

[31] Mia Ala-Juusela et al., "Positive Energy Building Definition with the Framework, Elements and Challenges of the Concept," Energies 14, no. 19 (2021), p8.

efficiency. In contrast to typical structures, which rely primarily on electric equipment such as electric heaters/coolers and artificial lighting, passive design strategies that take advantage of the local environment reduce energy consumption, NPEB maintains a pleasant level of illumination and warmth throughout the structure. The use of passive design techniques has a significant potential to lower energy use and contribute to NPEB[32].

Net-Positive Energy Buildings utilize passive design strategies to reduce energy consumption by exploiting the local climate. Passive design strategies use natural heating or cooling to achieve balanced interior conditions. The energy flow in passive design is natural such as radiation, conduction, or convection, without utilizing any electrical device. In a hot climate, keeping a building's interior comfortable requires slowing the rate of heat gains into the structure and promoting the removal of excess heat. This can be done by blocking heat from entering the system or removing it once it has.

2-8-3-2 Renewable Energy Systems of NPEBs

The NPEB should have onsite renewable energy as the primary energy source. In contrast, in NZEB, onsite renewable energy generation should at least partially meet the building's energy needs, whereas, in a NPEB, the requirement is to exceed the market. In addition to merely demanding the use of renewable sources, various criteria, such as price, regional accessibility, or the energy's fit for the demand (cooling, heating, or electricity), based on energy analysis, can be used to rank the priority of renewable options. For the off-site options, this criterion for selection may also be found in how close a renewable fuel source or renewable plant is, and it may even consider investments in off-site low- and zero-carbon energy projects. Renewable energy supply sources, such as solar panels, can be located on the building site or transported to the site through a general categorization and a ranking for preferred renewable energy sources, as represented in Fig (2.7).

[32] Gokula Manikandan Senthil Kumar and Sunliang Cao, "State-of-the-Art Review of Positive Energy Building and Community Systems," Energies 14, no. 16 (2021), p7.

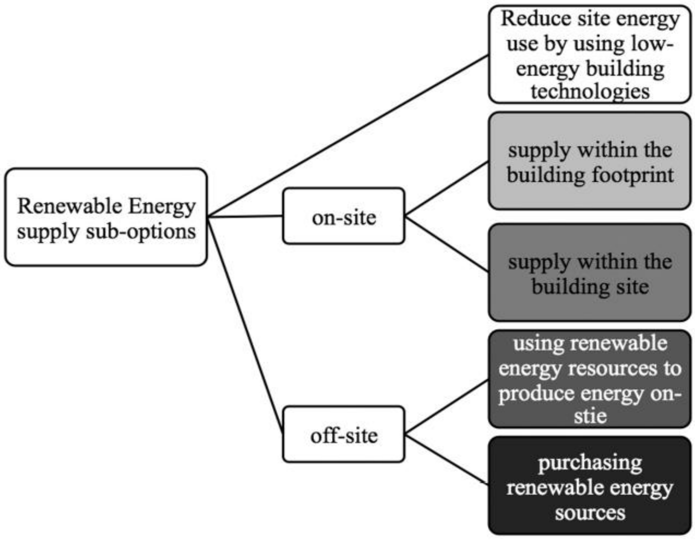

Fig.2.7: NPEBs renewable energy supply option hierarchy. [33]

2-8-4 Energy Storage

The broader adoption of renewable energy systems, such as those connected with NPEBs, depends critically on energy storage. Energy storage devices assist NPEBs in lowering the cost of the maximum demand fee for electricity from the utility grid, enabling the system to respond to demand, maximizing time-of-use, and serving as a backup power source.

2-8-4-1 Different Energy Storage Systems in NPEB

Net-Positive Energy Buildings employ active and passive energy storage techniques; a dynamic system necessitates mechanical and electrical equipment, while a passive system does not. A few burgeoning technologies that can store energy in NPEBs are compressed air energy storage, flow batteries, flywheels, chemical batteries, metal-air batteries, supercapacitors, and hydrogen storage systems. Among these most frequently used energy storage technologies are chemical batteries.

Chemical batteries are among these energy storage devices that are most frequently employed. Passive energy storage technology uses walls, windows, and floors to store, absorb, release, and distribute energy in the

[33] DEKD Kolokotsa et al., "A Roadmap Towards Intelligent Net Zero-and Positive-Energy Buildings," Solar energy 85, no. 12 (2011).

winter and abandon heat in the summer. A heat source is the ground quote heat exchanger.

2-8-4-2 Electrical Energy Storage Systems (EESS)

For electrical installations, electrical energy storage systems (EESS) are becoming more common. Electrical energy can be stored by EESS and used at a later time. The strategy is not new; battery-powered uninterruptible power supply, or UPSs, are a common kind of EESS that have been in use for a long time. There are no other uses for EESS. The use of EESS is growing for several reasons:

(A) By guaranteeing that the energy produced by renewable sources is available if those sources of energy become unavailable, it increases the effectiveness of renewable energy. EESS can be utilized to offer complete independence from the public supply or to guarantee that all energy generated can be used locally in addition to the grid supply.

(B) It provides electricity if the grid supply is lost, allowing, for instance:

(I) Data centers, other computers, and control systems are "shut down controlled" to avoid corrupting stored data, which would happen if power was cut off suddenly[34].

(II) Infrastructure and electrical and technological devices to be utilized in the event of a power loss.

(C) Grid support services, such as fast frequency response, supply and demand management, network restrictions, and power quality management, are made possible by it. These services aren't always found on generation sites; they could be combined over multiple locations.

(D) Decreases in the price of EESS, particularly lithium-ion batteries.

2-8-4-3 Types of Energy Storage

Types of Energy Storage technologies can be classified into five categories based on the form in which energy is stored figure(4.20).

[34] EO Ogunniyi and HCVZ Pienaar, "Overview of Battery Energy Storage System Advancement for Renewable (Photovoltaic) Energy Applications" (paper presented at the 2017 International Conference on the Domestic Use of Energy (DUE), 2017).

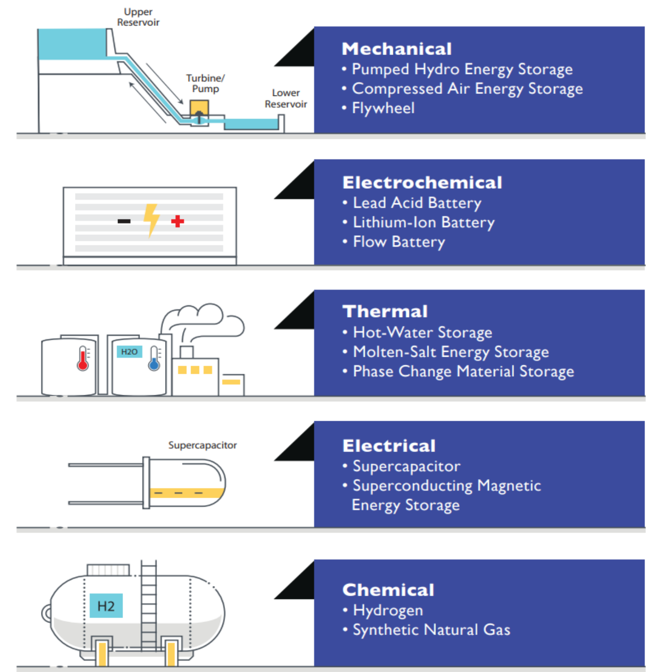

Fig.2.8: Types of energy storage. [35]

The scope of this thesis Briefing is limited to electrochemical storage technologies, as this is the predominant technology that is currently available to meet the needs of EESS.

The key considerations when selecting the batteries are:

(A) Capacity: Verify that the battery has enough capacity to meet the expected discharge requirement without being too large to impede full charging. Certain battery types are not suitable for full discharge, and incomplete charging can result in an early failure of the battery.

(B) Suitability: Verify that the batteries in the configuration that are used are compatible with the charge/discharge management parts.

(C) Environmental compatibility: Verify that the batteries can safely be installed, maintained, and decommissioned in the facilities designated to house the EESS. They should also be compatible with the surrounding conditions.

[35] Energy Markets Authority, *Energy Storage Systems* (Singapore, 2020).

(D) Battery disposal: When a battery's life is coming to an end, it must be disposed of according to applicable laws and without causing harm to the environment.

2-9 Social Framework for NPEBs

The NPEB definition focuses on technical traits and qualities. However, a broader approach is required to define and incorporate other NPEB framework components, such as emissions, life cycle aspects, and a human-centric approach. People spend the majority of their time in buildings. As a result, the human-centric approach is essential to the NPEB concept, ultimately influencing society. As a result, this method is used in the NPEB concept and framework to integrate human, societal-centric, and technical processes.

2-9-1 Indoor Environmental Quality

The notion of Net-Positive Energy Building describes the internal environment quality, which includes thermal, acoustic, and visual settings, as well as indoor air quality. Meeting specified thresholds for carbon dioxide, volatile organic compound content, air fluxes, and interior temperature is required for good indoor environment quality. Other factors to consider are daylight utilization and appropriate materials with sufficient acoustic insulation[36].

Many definitions emphasize user comfort and well-being. Instead, when conspiring NPEBs, it should be improved.

This is an essential consideration because it places the consumer at the center of the energy system without affecting his comfort or indoor environment hygiene. A better indoor environment leads to improved consumer satisfaction based on demand and behavior. The indoor environment is critical since it immediately influences the well-being of the residents. Furthermore, the end user should have some influence over the indoor climate. Many elements influence user comfort, including the structure's environment, tradition, culture, and usefulness.

2-9-2 User Participation

The social perspective is considered in NPEB since a building or dwelling space is associated with the individuals who live/work within a building/area where they spend most of their time. As a result, building

[36] Mia Ala-Juusela et al., "Positive Energy Building Definition with the Framework, Elements and Challenges of the Concept," Energies 14, no. 19 (2021), p9.

users want the structure to be adaptable in communicating with, responding to, and meeting their needs. The focus point of the framework and definition must be user acceptance and involvement. Because of the internet, information, and communication technologies, users can engage with the building based on their comfort and other demands. The user would have the option to pick via various devices, for example, indoor ventilation, temperature, lighting, and scheduling of several appliances.

The devices would have an easy-to-use interface for communication and selection and the interface would also allow for feedback on expenses, consumption profiles, air quality, energy savings in accordance with standards, compliance of functionality to user requirements, current emissions, emissions generated by specific selections, and other characteristics. A basic degree of service has been incorporated, as well as distinct controls and some user-friendly feedback or reporting.

2-9-3 Resilience and Data Security

The robustness of the NPEBs should be ensured; this will offer users energy security. Backup, storage, and grid support should be assured to avoid and compensate for any anticipated blackouts and other disruptions. Furthermore, the user would share data, make tailored choices, and interact with devices connected via the internet and other data-capturing equipment. As a result, based on general data protection standards, users' data security and privacy should be protected.

2-9-4 Economic Considerations

Net-positive energy is a component of the office market, and various economic issues must be examined. First and foremost, the NPEB should have a successful business model that includes revenue streams from market transactions. The NPEB should determine the payback period and return on investment. Renewable energy and other measurement technologies have comparatively significant investment costs. As a result, the payback period may be more extended than for a standard structure; nevertheless, enhanced energy savings, excess energy sales, emissions reduction, and user happiness should all be factored into the cost calculations. Currently, the industry and investors are concerned about investment costs. Prices in NPEB should be based on life cycle costs rather than investment costs alone; total life cycle costs and benefits should be evaluated.

On-site energy production may benefit stakeholders financially. Property investors, for example, gain in various ways from onsite energy production. For starters, onsite energy generation can save building operating costs. Second, onsite manufacturing may protect buildings from increasing energy prices and environmental regulations. Third, as customers become more environmentally conscious, onsite production may be a feature investor may use to increase rental income. Finally, onsite energy production is likely to be adopted by property investors if the capitalized value of the advantages surpasses the investment costs.

2-10 Different Ways to Categorize Net-Positive Energy Buildings

According to the building's border, many NPEB kinds could exist in the same design provided by the European Energy Research Alliance (EERA) for favorable energy districts (NPED) based on the building's border. The NPEBs could be split into three main categories founded on the boundary according to EERA, here applied to a building level:

1. An autonomous NPEB is a self-sufficient structure with energy consumption, supply, and storage inside a predetermined building boundary. Onsite renewable energy sources cover the market. The external grid is not used to import energy, but extra energy could be exported to it.

2. A dynamic NPEB that a building with a higher onsite renewable energy supply than the demand inside the specified building perimeter is referred to as the grid, and other facilities outside the perimeter are in contact with a building.

3. Virtual NPEB that a building with a virtual or no specific fixed boundary. Storage facilities for renewable energy can be found outside the boundaries of a structure. The building's energy demand should be less than the total supply of onsite renewable energy and remote generation sources.

Finding the NPEB boundary at the beginning is crucial. Numerous elements, including the city's topography, location, local laws, the building's kind, construction, the available energy infrastructure, market, and financial model, and the environment, can affect how the building's border is determined.

2-11 Conclusion of Chapter Two

Net-Positive Energy buildings have several characteristics, as follows:

1. A Net-positive energy approach involves a larger set of energy exchanges and partnerships.
2. The broader spatial framing of net positive potentially captures building energy/carbon and transportation energy/carbon relationships.
3. The notion of net positive potentially extends the timeframe to the entire lifecycle and thereby captures operating energy.
4. Buildings, landscapes, infrastructure, and services must collectively be considered elements of a system/neighborhood as being directed at providing the highest import–export, and generation–consumption performance. This extends beyond technical systems and considers inhabitant behavior and engagement critical to achieving successful performance.
5. Striving for the lowest waste of energy during the processes of export-import and the lowest transformation of a part of the energy to its lower quality forms. Improving how, when, and where energy is exchanged within the system necessary to accomplish this goal. As in figure (2.9) the summary of net positive energy buildings system.

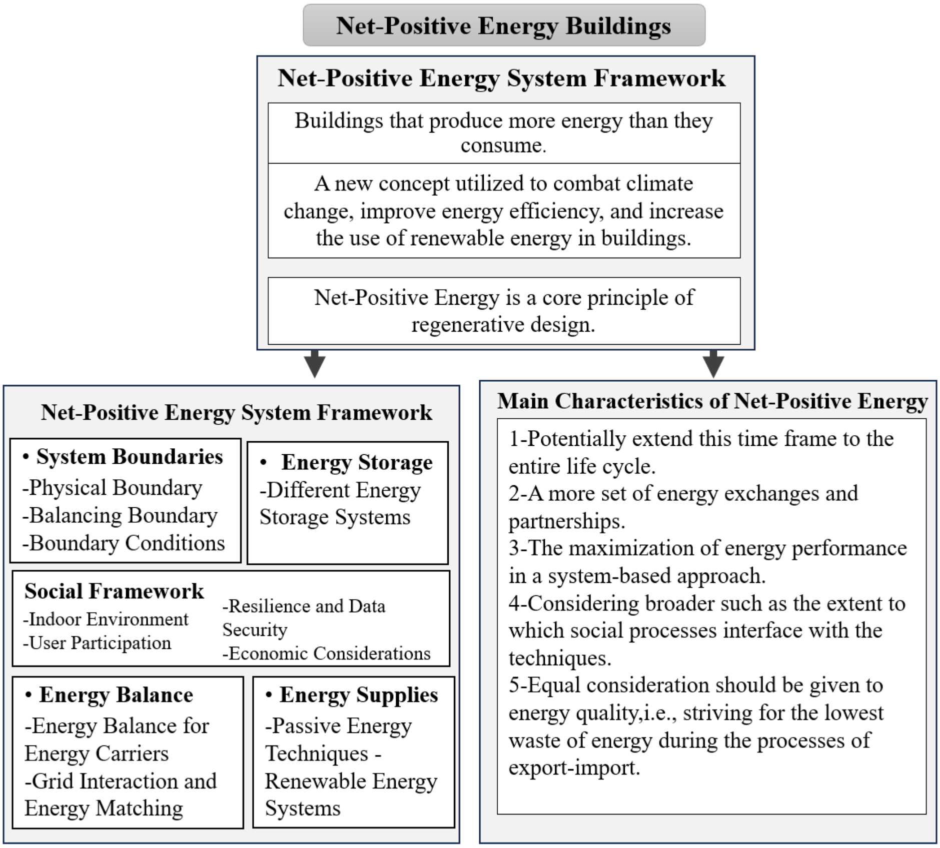

Fig.2.9: Summary of net positive energy buildings system. [37]

[37] Author.

CHAPTER THREE

Case Studies of Regenerative Office Buildings

3-1 Introduction

Buildings are a cultural and functional necessity for humans. They serve as the spatial and environmental setting for human activity. They are a shelter that provides residents with the essential safety, space, and comfort for their demands. Buildings are cultural manifestations of the aspirations and technological capabilities of the civilization to which they belong. Moreover, the built environment is responsible for significant environmental impacts.

While most previous and existing attempts have targeted minimizing environmental impacts, regenerative design and development go beyond reduction and aim to restore and support environmental, social, and economic flows. Yet, only a few projects have demonstrated a regenerative outcome. Building design is influenced by technological improvements, which can have a significant impact. While air conditioning, electric lighting, elevators, and other building technologies have given architects more creative flexibility and residents more convenience and comfort, their use has greatly reduced building operational energy and associated GHG emissions. Furthermore, various events, developments, and discoveries have altered public attitudes and the significance of environmental challenges since the inception of modern environmentalism in the 1960s. It has since influenced building design and construction methods. This chapter discusses some buildings that introduce regenerative design principles and net positive energy with an integrated system. These techniques are under the living Building Challenge (LBC) system.

3-2 The selection criteria of Case studies

The thesis discusses in this chapter three office buildings The Bullitt Center building in USA, the PAE Living building in USA, and the 78 Corlett Drive building in South Africa. The criteria for choosing: "The Bullitt Center" building and "PAE Living" building are:

- The two projects achieved the Living Building Challenge (LBC) certification, which could be a reference repeated in developing countries such as Egypt.

- The design of "The Bullitt Center" and "PAE Living Building" buildings contains architectural designs and mechanical techniques that suit buildings in different climates although the two buildings are in cold climates and don't need cold systems.

- Although the two buildings have LBC certificated, both "PAE Living" and the " Bullitt Center" buildings have used different techniques and strategies.

The criteria for choosing the 78 Corlett Drive building as the first office building in South Africa to be awarded the Living Building Challenge Petal certification. However, the building has not achieved the seven petals such as the PAE Living and the Bullitt Center buildings. Still, it has achieved Net-Positive Energy, making it a unique reference for African buildings.

3-3 The Bullitt Centre Project Summary

Situated on the border of Seattle, Washington, the Bullitt Center opened its doors in April 2013[1] as shown in figure (3.1) and (3.2). one of the most sufficiently certified regenerative projects in the world. Funded primarily by the Bullitt Foundation, a nonprofit organization committed to sustainability in the Pacific Northwest Situated on the border of Seattle, Washington[2].

Fig. 3.1 Seattle's Bullitt Center[3].

[1] Jim Hanford, "The Bullitt Center Experience: Building Enclosure Design in an Integrated High Performance Building" (paper presented at the Proceedings of the BEST4 Conference (April 13, 2015), 2015).

[2] Julie Homchick Crowe, "Architectural Advocacy: The Bullitt Center and Environmental Design," *Environmental Communication* 14, no. 2 (2020).

[3] Robert Peña, Chris Meek, and Dylan Davis, "The Bullitt Center: A Comparative Analysis between Simulated and Operational Performance," *Technology| Architecture+ Design* 1, no. 2 (2017).

Fig.3.2: The Bullitt Center plans[4].

One of the most sufficiently certified regenerative projects in the world. Funded primarily by the Bullitt Foundation, a nonprofit organization committed to sustainability in the Pacific Northwest. Bullitt Center is composed of a 6-story, 51,990-square-foot[5].

[4] Heather Burpee, "Health Impacts of Green Buildings" (paper presented at the The Value of Design: Design & Health, Washington, D.C, 2014).

[5] Julie Homchick Crowe, "Architectural Advocacy: The Bullitt Center and Environmental Design," Environmental Communication 14, no. 2 (2020).

The center's objective is not to create revenue but to propel change in the marketplace faster and further by showing what's achievable today. The International Living Futures Institute independently verified the Center's construction, operational effectiveness, and user satisfaction, awarding it the Living Building Challenge designation. This title belongs to the most notable building[6]. Table (3.1) shows the overview of the building. Materials not harm people or the environment were used to construct the structure of the building. It comprises a 250-year heavy timber, concrete, and steel structure clad in a 50-year envelope, adorned with a 25-year photovoltaic array[7].

Table.3.1: The Bullitt Centre building overviews

Project Overview			
Location	Seattle, Washington	**Owner**	Bullitt Foundation
First Occupancy	April 2013	**Project Manager**	PAE Consulting Engineers
Occupant	145 FTE, plus about 3,000 visitors annually	**Site Area**	51,990 gross ft2 (4,830 m2) 50,000 ft2 conditioned area (4,645 m2) 44,766 ft2 net rentable area (4,159 m2)
Architect	The Miller Hull partnership	**Building Footprint**	10,076 ft2 (936 m2)
Height	Six stories	**Certifications**	Living Building Challenge (version 2.0)

3-4 Bullitt Center Building and Living Building Challenge (LBC)

In April 2015, the Bullitt Center achieved the status of a Living Building, as certified (version 2.0) by the International Living Future

6 Robert Peña, Chris Meek, and Dylan Davis, "The Bullitt Center: A Comparative Analysis between Simulated and Operational Performance," Technology| Architecture+ Design 1, no. 2 (2017).

7 Jim Hanford, "The Bullitt Center Experience: Building Enclosure Design in an Integrated High-Performance Building" (paper presented at the Proceedings of the BEST4 Conference (April 13, 2015), 2015).

Institute (ILFI)[8]. A Living Building must adhere to 20 design imperatives in seven performance areas site, water, energy, health, materials, equity, and beauty, and be both Net-Positive Energy and Net-Zero Water for 12 months of that's a significant achievement[9]. Where the design of the Living Building Standard can be transformed into rich, dynamic, and aesthetically pleasing visualizations of the building's ecosystem services at any time, the seven "Petals" of the Living Building Standard provide a natural[10]. The Bullitt Foundation and the Bullitt Center encourage vital education by showing what's possible and reduced. The actions keep the project to be more than just another office building. It enables it to reach a higher potential. The certificate is given for creating a structure that produces long-term outcomes and motivates others in development and commercial real estate to do the same. The Bullitt Center building achieved seven petals as follows[11]:

- **Site**: The area supports a transit-, bike-, and pedestrian-friendly lifestyle.
- **Water**: Rainwater is gathered from the roof, kept in a subterranean cistern, and used inside the structure.
- **Energy**: A solar array produces more than electricity as the building uses.
- **Health**: The building's accessible staircases, movable windows, and elements that encourage walking and resource sharing all work to improve the health of its residents.
- **Beauty**: The area is made more beautiful by striking architecture, a creative photovoltaic array, native plants and a green roof, enormous structural timbers, and a renovated pocket park.
- **Material**: PVC, cadmium, lead, mercury, and hormone-mimicking chemicals are among the "Red List" hazardous

[8] Jim Hanford, "The Bullitt Center Experience: Building Enclosure Design in an Integrated High-Performance Building" (paper presented at the Proceedings of the BEST4 Conference (April 13, 2015), 2015).

[9] Robert Pena, "Living Proof: Seattle's Net Zero Energy Bullitt Center" (University of Washington, 2014).

[10] John Dylan Davis, "Eboss-Evolutionary Building Operations Systems Solver" (University of Washington, 2017).

[11] Robert Pena, "Living Proof: Seattle's Net Zero Energy Bullitt Center" (University of Washington, 2014).

compounds that are frequently discovered in building components, but they are not present in this building.

- Equity: Large movable windows that allow employees to enjoy natural light and fresh air are located 30 feet or less from each desk.

3-5 Bullitt Center Building Design

Integrated design is a comprehensive approach that sees the building as an interconnected system rather than a collection of discrete components. It is not about the separate elements but about how they operate together. Integrated design occurs when building elements perform several purposes as shown in the Bullitt Center building in figure (3.3)[12].

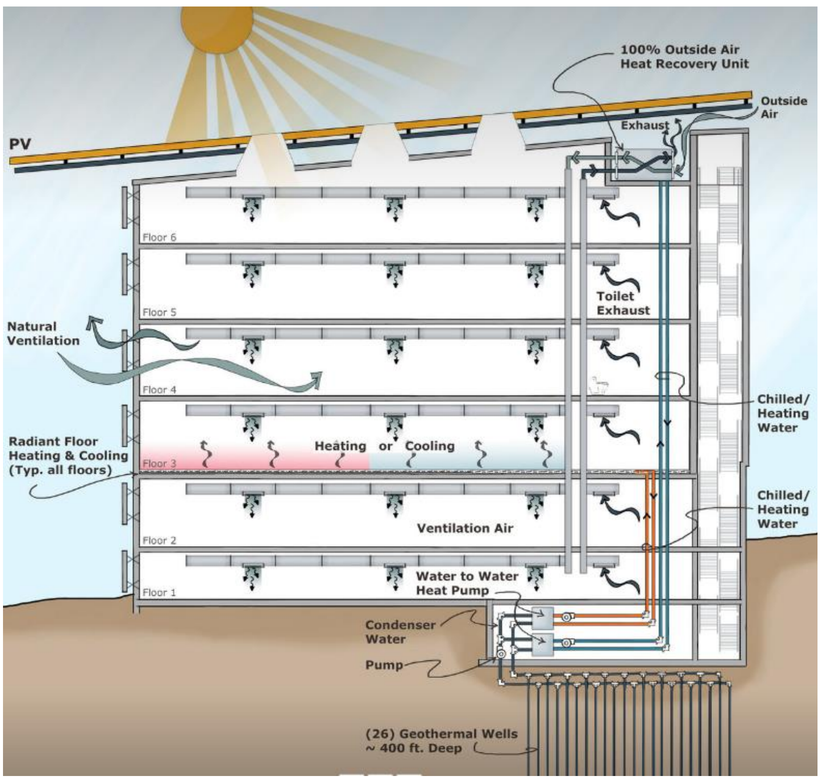

Fig3.3: Bullitt center building integrated architecture and mechanical system[13]

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[12] Robert Peña, Chris Meek, and Dylan Davis, "The Bullitt Center: A Comparative Analysis between Simulated and Operational Performance," Technology| Architecture+ Design 1, no. 2 (2017).

[13] https://archello.com/, "Bullitt Center," in *The Miller Hull Partnership as Architects* (Archello.com2014).

Integrated design, as a design process, comprises multidisciplinary collaboration from conception to construction completion and delivery[14]. Integrated design solutions combine architectural and mechanical aspects to achieve greater performance than they could on their own. The Bullitt Center's architectural concepts are ubiquitous in modern constructions, and the technology depicted. However, just a few buildings have wholly integrated the Bullitt Center's cutting-edge technologies and high-performance design ideas. The most crucial stage in establishing a super high-performance building is the owner's and the design and construction team's commitment to precise performance targets[15].

3-5-1 Solar Array

The Bullitt Center building produces more electricity than it uses, with 575 solar panels on the roof and a 14,000-square-foot array to generate electricity. The system generated 243,671 kwh, and the building consumed 152,878 kwh, or 63 percent of the energy produced. Since solar panels are light-sensitive, solar intensity and sky conditions significantly impact production values as shown in figure (3.4)[16].

Fig.3.4: Solar Panels on the Bullitt center[17]

[14] Julie Homchick Crowe, "Architectural Advocacy: The Bullitt Center and Environmental Design," Environmental Communication 14, no. 2 (2020).

[15] Jim Hanford, "The Bullitt Center Experience: Building Enclosure Design in an Integrated High-Performance Building" (paper presented at the Proceedings of the BEST4 Conference (April 13, 2015), 2015).

[16] Jim Hanford, "The Bullitt Center Experience: Building Enclosure Design in an Integrated High-Performance Building" (paper presented at the Proceedings of the BEST4 Conference (April 13, 2015), 2015).

[17] https://archello.com/, "Bullitt Center," in The Miller Hull Partnership as Architects (Archello.com2014).

The Bullitt Centre generates far more electricity than it consumes during the summer and less during the winter[18].The Bullitt Centre utilizes Seattle's electrical grid to "store" surplus electricity. In the summer, surplus energy is stored through excess injecting electricity onto the grid when production is high. In the winter, when production is minimal, the structure uses stored grid electricity.

3-5-2 Windows and Shades

As a design process, integrated design entails multidisciplinary collaboration from conception to construction completion and delivery. Integrated design solutions integrate architectural and mechanical aspects to obtain higher performance than either could alone. The architectural concepts of the Bullitt Center are common in modern structures, and the technology illustrated in Figure (3.5)(3.6) is widely available.

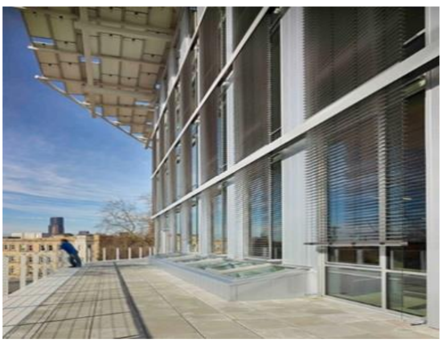


Fig3.5: The Bullitt Center shades.[19]

Fig.3.6: The Bullitt Center windows.[20]

Building occupants' access to daylight is a requirement of the LBC certification. The skin is a system of layers used in different varieties to gain optimal thermal and light qualities[21]. In addition, an integrated system of triple pane glazing and operable window help maintain interior temperatures, automated exterior veneration blinds, and daylight control is used for internal blind. All these techniques serve a control building

[18] Robert Pena, "Living Proof: Seattle's Net Zero Energy Bullitt Center" (University of Washington, 2014).

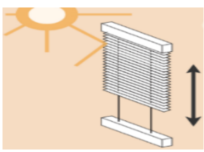
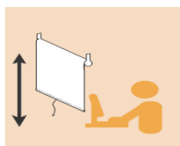
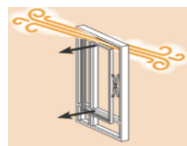
[19] Julie Homchick Crowe, "Architectural Advocacy: The Bullitt Center and Environmental Design," Environmental Communication 14, no. 2 (2020).

[20] Robert Pena, "Living Proof: Seattle's Net Zero Energy Bullitt Center" (University of Washington, 2014).

[21] Archello, "Bullitt Center," in The Miller Hull Partnership as Architects (https://archello.com/: Archello, 2014).

temperatures and CO_2 for the best thermal comfort as shown in table (3.2)[22]. The skin is a system of layers that are integrated in various ways to produce the finest thermal and solar qualities feasible. The deployable stainless-steel blinds form the building's outermost layer. In the summer, when solar heat gain can be an issue, the shades deploy to disperse direct rays before they contact the glass. In the winter, the blinds increase natural light in the office while protecting workstations from direct sunlight[23]. Cooler air could enter the building through the moveable windows at night to drain heat from the interior, preparing its thermal mass to absorb extra heat the next day. When the outside temperature is over 45°F, windows can be opened for night flush cooling, but only if the outside air temperature is above 70°F within 24 hours.

Table3.2: The different windows control systems in Bullitt Center.[24]

Different Windows Control Systems		
		
Thermal control employs exterior shades to scatter direct beams and maintain the interior temperature.	**Daylight Control** used for interior blinds reduces glare on the workspace.	**Air Control** used for operable windows to move straight out to maximize ventilation.

3-5-3 Radiant Cooling and Heating

The building is cooled (and heated) by an intensive system of veins or hydronic radiant tubing that coils a few inches underneath the concrete overlay of each floor. The tube's formal name, cross-linked polyethylene, is usually shortened to PEX. A unique mix of water and glycol dashed inside the lines, cooling or warming the concrete slab, efficiently radiating into the occupied spaces. Twenty-six geothermal wells 400 feet below the

[22] STUART Cowan et al., "Optimizing Urban Ecosystem Services: The Bullitt Center Case Study," *Ecotrust: Portland, OR, USA* (2014).

[23] Peña, Meek, and Davis, "The Bullitt Center: A Comparative Analysis between Simulated and Operational Performance," p 167.

[24] Robert Pena, "Living Proof: Seattle's Net Zero Energy Bullitt Center" (University of Washington, 2014).

Bullitt Center building serve as the heat source for the radiant heating system as shown in figure (3.7).

Fig.3.7: Tubing for in-floor radiant heating or cooling[25].

3-6 Energy Performance of The Bullitt Center Building

E Quest/DOE 2.2 was used for hourly research on building energy use, predicted use, internal loads, and the planned architectural, mechanical, and electrical systems.[26]. To predict energy use, other design team members explored hundreds of variations on organizing the photovoltaic arrays through parametric analysis using Grasshopper 3d + Rhino. At the end of this iterative design process, the energy models for the Bullitt Center predicted an annual energy use index (EUI) of 16 kBTU/SF year[27]. During its first full year of operation, the building generated 114,085 kwhrs more electricity than it consumed from May 1, 2013, to April 30, 2014. Based on a gross floor area of 50,142 SF, the building's actual EUI was 9.4 kBTU/SF per year, using 41.7% less energy than the expected EUI of 16.1 kBTU/SF per year. Compared to a building that satisfies the minimal 2009 Seattle Energy Code (EUI = 42 kBTU/SF year) figure (3.8).

The Bullitt Center building energy performance was 77% better[28]. The actual electricity generated was 251,885 kwhrs, 2.3% less than predicted. For nearly three years of operation, the Bullitt Center building energy performance has been better than expected and has been net positive for the last two years. During the design phase, whole-building

[25] Peña, Meek, and Davis, "The Bullitt Center: A Comparative Analysis between Simulated and Operational Performance,".

[26] Linda Reeder, *Net Zero Energy Buildings: Case Studies and Lessons Learned* (Routledge, 2016).

[27] Robert Pena, "Living Proof: Seattle's Net Zero Energy Bullitt Center," *University of Washington, Department of Architecture* (2014).

[28] Ibid.

energy simulations projected an Energy Use Intensity (EUI) score of 16 $kBtu/ft^2$-yr[29].

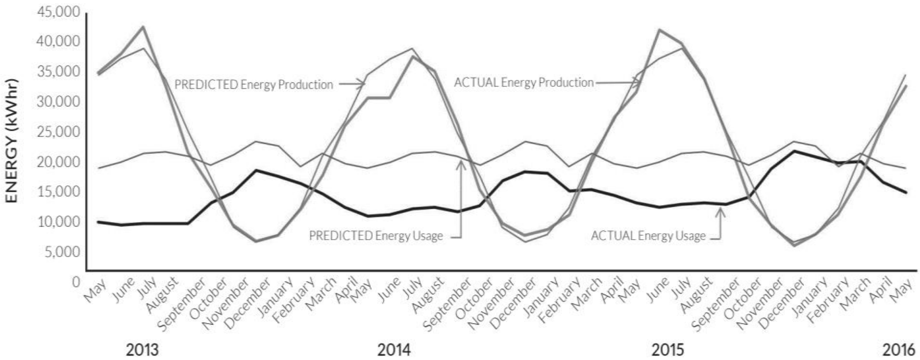


Fig3.8: Simulated versus operational energy production and use[30].

3-7 PAE Living Building

PAE Engineers was looking to develop a new building in Portland to serve as its corporate headquarters, as the company had outgrown its existing office space. PAE Living building is not just “less bad.” It goes beyond reducing carbon emissions to create a “carbon negative” building by combining a one-time offset of all embodied emissions and a Net-Positive Energy design that produces more renewable energy than the building uses over a year figure (3.9).

Fig.3.9: PAE Living Building[31].

[29] Ibid.

[30] Robert Peña, Chris Meek, and Dylan Davis, "The Bullitt Center: A Comparative Analysis between Simulated and Operational Performance," Technology| Architecture+ Design 1, no. 2 (2017), p167.

[31] PAE, "Pae Living Building," (https://www.pae-engineers.com: PAE, 2022).

PAE is a tenant. The PAE Living Building is regenerative, contributes positively to society, and represents a vision to help solve the planet's energy and water challenges[32]. The PAE Living Building is located in a former parking lot in Portland, Oregon. The project goal was to help achieve the city's 2050 renewable energy targets 30 years ahead of schedule. Table (3.3) shows the overview of the project. Revitalize and complement the neighborhood and historic district. Shown in plans of first floor and roof figure (3.10) and (3.11). Thirdly, a replicable, the developer-led solution to inspire future living building development[33]. The PAE Living Building facade is designed to reinforce the national historic district. However, on closer inspection, the façade seamlessly integrates many more responsibilities. The building's gridded facade, meant to reference the area's historical architecture, is made of regionally sourced brick and high-performance, fiberglass-framed window structural design built to Risk Category (RC) IV. PAE living building is meant to last 500 years; for several reasons: a strong seismic core to withstand a powerful earthquake, long-lasting materials like local wood, an open floorplan that enables flexibility for future residents, and the building structure's seismic resilience is assessed at Category IV, the same level as significant structures like fire stations and hospitals. The architectural concept combines the appearance and feel of a historic neighborhood with the best energy performance and sustainability criteria achievable[34].

Table.3.3: PAE Living Building overview[35]

Project Overview			
Location	Portland, Oregon	**Architect**	ZGF Architects
Completion date	2021	**MEP Engineers and Technology design**	PAE Consulting Engineers
Owner	Multiple Owners	**Size**	58,700 sq. ft
Certifications	Pursuing Full Living Building Certification (version 3.0)	**Height**	Five stories

[32] KPFF "Pae Living Building," (https://www.kpff.com: KPFF.com, 2021).
[33] PAE, "Pae Living Building," (https://www.pae-engineers.com: PAE, 2022).
[34] nextportland, "Pae Living Building Receives Design Advice " (https://www.nextportland.com: nextportland.com, 2019).
[35] PAE, "Pae Living Building."

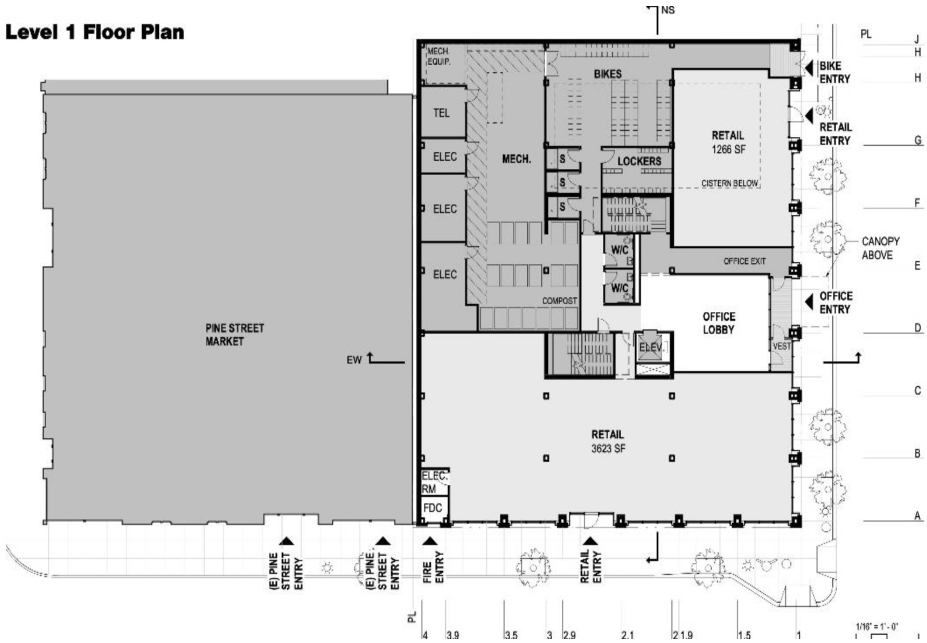


Fig.3.10: First floor of PAE building[36].

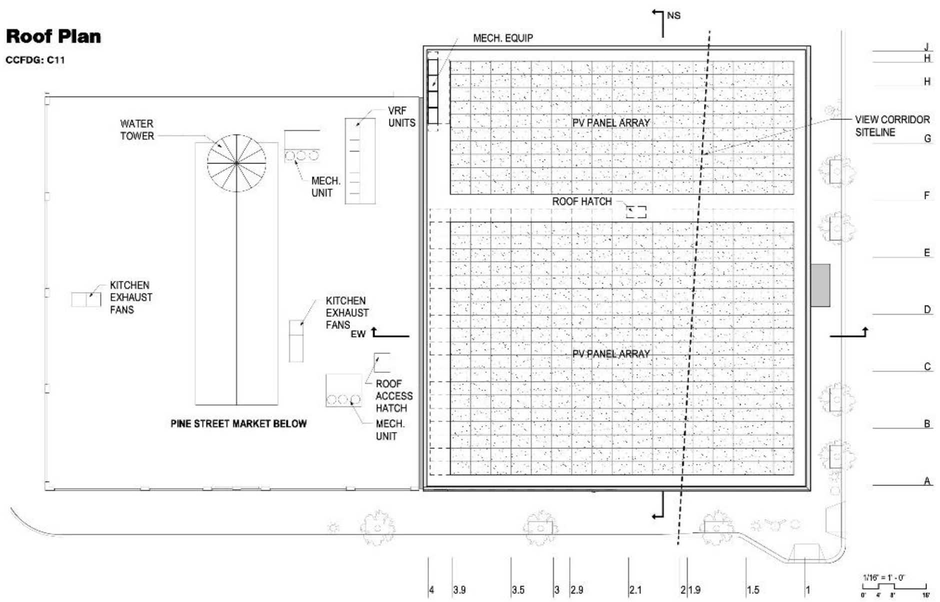


Fig.3.11: Site roof plan[37].

[36] Ibid.

[37] ZGF "The Pae Living Building," in *The World's First Developer-Driven Living Building* (www.zgf.com: zgf.com, 2023).

ILFI's Red List standards are met by healthy materials; abundant daylight, views, movable windows, and other biophilic solutions improve occupant health, comfort, and productivity. The main floor houses retail space, a tenant exercise center, showers, restrooms, lockers, and bike storage. PAE occupies roughly 33,000 square feet (3,066 square meters) of office space on floors one through four. The remainder of the area will be rented[38].In addition to the efficiency and seismic components, the building will be designed to optimize the health and well-being of occupants through ample daylighting and views, natural ventilation, biophilia, and healthy building materials[39]. A complete list of sustainability and design features can be found on PAE's project highlight. PAE Living is the first structure to employ a developer-led model. Investors and several locals joined the project in the hopes of making a profit. The project continually weighed financial factors such as cost, return on investment, and finding a path to a Living Building. As a result, it developed an innovative, repeatable strategy that reduces the affordability barrier for potential investors, paving the door for more living buildings[40].

3-8 PAE Living Building and Living Building Challenge (LBC)

PAE Living building achieved the status of a Living Building Challenge, as certified (version 3.1) by the International Living Future Institute (ILFI). PAE delivers the most value by leading project teams in identifying, analyzing, and evaluating all feasible systems and solutions to secure all seven Petals, or performance problems, to obtain full certification as shows in figure (3.12).

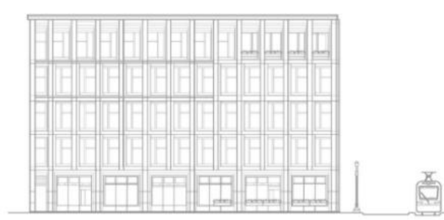


Fig.3.12: The Living Building Challenge is organized into seven areas[41].

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[38] nextportland, "Pae Living Building Receives Design Advice ".
[39] Ibid.
[40] ZGF "The Pae Living Building," in The World's First Developer-Driven Living Building (www.zgf.com: zgf.com, 2023).
[41] nextportland, "Pae Living Building Receives Design Advice " (https://www.nextportland.com: nextportland.com, 2019).

Each Petal is broken into 20 imperatives or needs the construction must meet. Finally, certification may only be obtained when the installation has been operating for twelve months. The prize is given for creating a structure that produces long-term outcomes and motivates others in development and commercial real estate to do the same[42].

3-9 PAE Living Building Design

PAE Living is a union of architectural principles and mechanical solutions that work together to achieve higher performance than they could on their own[43]. The design principles used in the PAE Living structure are quite typical in modern structures, and the technology is easily available. Only a few buildings, as shown Table (3.4), have fully incorporated the cutting-edge technologies and high-performance design principles used in the PAE Living building.

Table3.4: PAE Living building integrated architecture[44]

Energy	Onsite and dedicated offsite solar and onsite battery storage allows net positive energy production and link to the city grid.	**Water**	100% of the building's water demand is collected and treated onsite.
Seismic	The structure is designed for the same seismic performance required for hospitals and fire stations.	**Workplace**	Daylight, operable windows, views, and other biophilic strategies support occupant health, comfort, and productivity.
Investment	The first developer-led commercial Living Building proves the business case and creates a pathway for others.	**Material**	Sustainable and healthy building materials include Pacific Northwest cross-laminated timber approved by the Forest Stewardship Council.
Equity	The energy produced by solar PV will be shared by a local non-profit.	**Nutrients**	Multistory vacuum flushes composting toilets lower water use and transforms waste into a rich nutrient source.

[42] Ibid.

[43] LBC, "Living Building Challenge 4.0 : A Visionary Path to a Regenerative Future," (International Living Future InstituteSM, 2019).

[44] nextportland, "Pae Living Building Receives Design Advice " (https://www.nextportland.com: nextportland.com, 2019).

The PAE building used a radiant cooling and heating system where the building is cooled (and heated) by an intensive system of veins or hydronic radiant tubing that coils a few inches underneath the concrete overlay of each floor. And also, The PAE building used all energy-efficient electrical devices. The photovoltaic panel and battery system includes a 133-kW PV array on the roof, an offsite 215-kW PV array, and a two-way connection to the city's electrical grid as shown in figure (3.13).

It allows PAE buildings to operate temporarily in a unique low-energy mode while wholly disconnected from the grid (such as because of a blackout) and run off the grid for up to 100 days over the summer[45]. Onsite and dedicated offsite solar and onsite battery storage enable net positive energy output and grid connectivity. All the energy the building uses is generated by onsite and offsite photovoltaics.

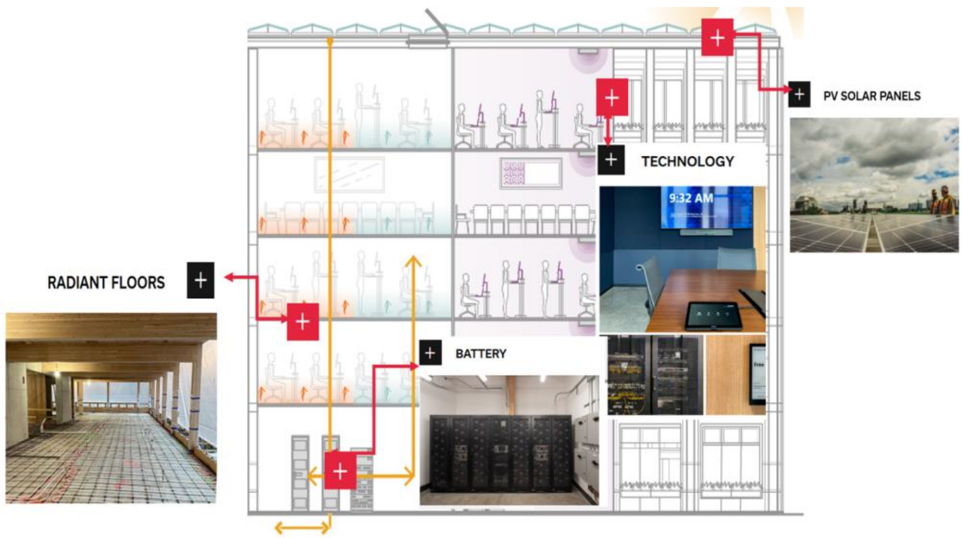

Fig.3.13: Energy strategies in PAE Living Building[46]

Battery storage allows the building to operate entirely on batteries and net meters in the downtown Portland network, a first in the country. At the same time, Onsite and dedicated offsite solar and onsite battery storage enable net positive energy output and grid connectivity. Extra energy is stored on-site in a battery system. According to the team, the system contains two-way connections that allow electricity to be transmitted to the city's grid, which is a first in this region of Portland. The

[45] KPFF "Pae Living Building," (https://www.kpff.com: KPFF.com, 2021).

[46] ZGF "The Pae Living Building," in The World's First Developer-Driven Living Building (www.zgf.com: zgf.com, 2023).

city's 2050 renewable energy targets will be met 30 years ahead of schedule[47].

3-9-1 Solar Arrays

The PV Array at the PAE living building generates 368,000 kWh hours of electricity each year, some of which are generated by the building's rooftop solar panels. Nevertheless, the building does not have sufficient roof space for the amount of solar array needed. In addition, historic-district rules prohibit roof overhangs, making meeting the net-positive energy imperative onsite unattainable.

PAE's core group benefited from a 2018 LBC offsite power generation exception to solve this issue. They are intended to promote Living Buildings in thick urban settings by funding a power array on the nearby Renaissance Commons affordable housing that would count toward PAE's net-positive energy. That includes a 133-kW on-site rooftop solar array and 195-kWkW off-site solar array on a partnering affordable housing unit as shown in figure (3.14) and (3.15). This offsite array encourages neighborhood renewable power and fills the LBC equity obligation, requiring the team to contribute half a cent or more of every dollar spent on the project to a charity or ILFI's Living Equity Exchange Program.

Fig.3.14: The project PV solar energy offsite[48].

Fig.3.15: The PAE on-site solar array[49]

[47] PAE, "Pae Living Building," (https://www.pae-engineers.com: PAE, 2022).
[48] PAE, "Pae Living Building," (https://www.pae-engineers.com: PAE, 2022).
[49] Ibid.

3-9-2 Windows

As illustrated in Figure(3.16), the windows are double-paned fiberglass windows with a very low u-value, which the triple-paned windows were supposed to employ. Furthermore, moveable windows ventilate or cool 70% of the building's perimeter spaces. A high-performance envelope and radiant floor heating and cooling minimize cooling and heating requirements to less than half of what specific building needs of this scale would require.

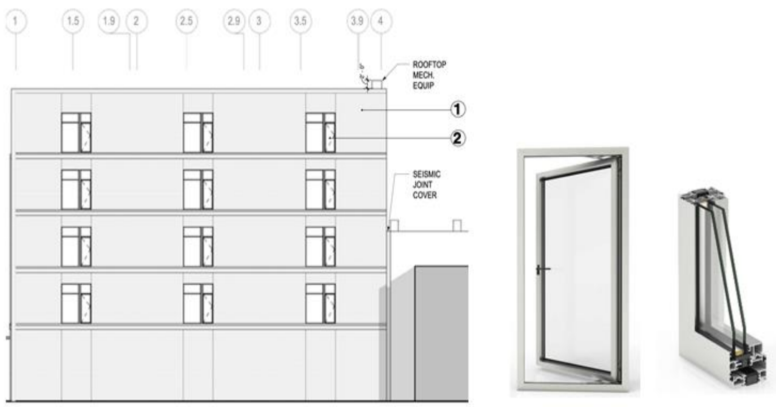

Fig.3.16: PAE Living building windows with details[50].

3-10 Energy Performance of PAE Living Building

A thorough project model was created, accounting for every component of the building's energy use, and then fine-tuned for maximum efficiency as shown figure(3.17) and(3.18). The natural energy flows of fresh air and light from the building's windows, as well as the energy generated by the rooftop PV, were considered in the model. To accommodate the utility limits, a battery storage system was also built for charging and discharging the battery. Early modeling showed that the PAE Living Building is projected to use just 18.6 kBtu/sqft per year, which is 80% lower than a typical office building.

The energy generated will supply 103% of the building’s demand while providing low-cost power to the residents of the housing unit. Microgrid with a 250 kw battery allows the building to island itself during power loss. Where projected energy EUI (Energy Use Index) of 18.6

[50] ZGF "The Pae Living Building," in The World's First Developer-Driven Living Building (www.zgf.com: zgf.com, 2023).

kBtu/SF/YR vs typical Portland office building built to code of 40.8 kBtu/SF/YR which is 73% better than a typical existing building and 81% better than Architecture 2030 targets.

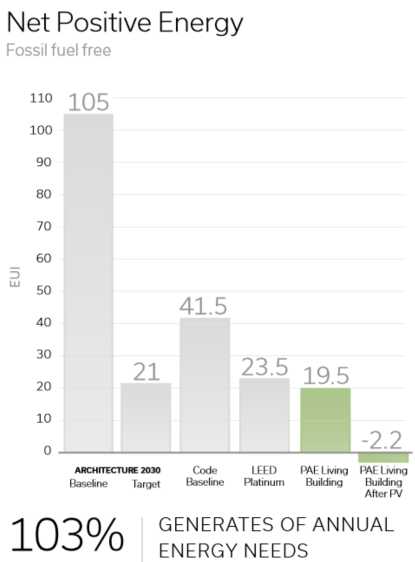

Fig.3.17: PAE energy performance[51].

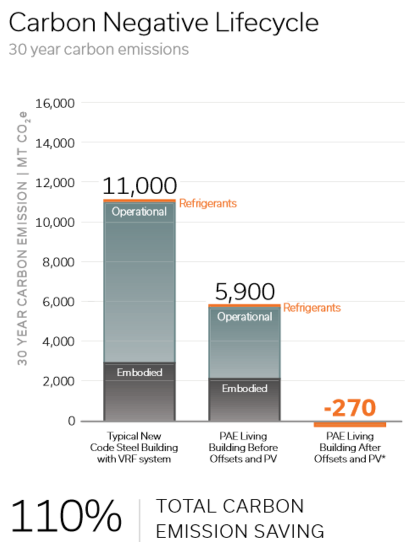

Fig.3.18: PAE carbon emission[52].

3-11 Comparison between Bullitt Centre building and PAE Living Building

Comparison between Bullitt Centre building and PAE Living Building in the design of architecture, mechanical and electrical, and the investment Table (3.5).

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[51] PAE, "Pae Living Building," (https://www.pae-engineers.com: PAE, 2022).
[52] ZGF "The Pae Living Building," in The World's First Developer-Driven Living Building (www.zgf.com: zgf.com, 2023).

Table3.5: The comparison of The Bullitt Center" and "PAE Living Building.

	Comparison Elements	The Bullitt Center	PAE Living Building
Architecture Design	**The Year of LBC Certifying**	2013	2022
	Rating System	ILFI Living Building Challenge 2.0 Full Certification	ILFI Living Building Challenge 3.1 Full Certification
	Square Feet	52.000	58.000
	Floors	Six stories	Five stories
	External Shades	Exist external shades	There are no external shadows
	Windows	- Triple-glazed window - Automated operable window	- Double-glazed window - Partial operable/ manual windows
	Basement	There is a basement	No basement
	Dedicated Bike Room	No dedicated bike rooms	There is a dedicated bike room
	Dock	There is a loading dock	No loading docks
	Stairs	External irresistible stair	Internal architecture exits stairs
	Lobby	2 Lobby	1 Lobby
	Construction Materials	NLT (Nail Laminated Timber)	CLT (Cross Laminated Timber)
Mechanical Design	**HVAC System**	- Ground source geo-exchange - Roof-mounted central heat recovery dedicated outside air ventilation	- Air source heat pump - Floor-by-floor heat recovery dedicated outside air ventilation unite
	Hydronic Radiant Floor	There is a hydronic radiant floor	There is a hydronic radiant floor
	Supplemental AC	Water source heat pumps serving radiant ceiling panel	Air-cooled VRF fan coil units.

Lighting	**Lamps**	0.4 Watt/SF	-0.58 Watt/SF fully lit -0.15 Watt/SF with daylight controls
	Daylight	82% of the building is daylight	65% of the building is daylight
	LED Lighting	Energy-efficient LED fluorescent task lights, ambient	LED Lighting with nighttime sweeps
Electrical	**Electricity from PV arrays**	242 KW -Onsite PV system	328 KW - 132.6KW Onsite - 195.4 KW Offsite
	Energy Use Intensity	16.0 EUI	18.6 EUI estimated includes retail program
	Batteries	No battery	Battery 125 KW / 250
	Microgrid	No microgrid	Full microgrid
Investment	**Company**	Bullitt Foundation	Multiple Private investors

3-12 78 Corlett Drive

"78 Corlett Drive" it is the first office building in South Africa to be awarded the Living Building Challenge Petal certification. Designed by architect Enrico Daffonchio, the building incorporates cutting-edge sustainable technology, making it the most sustainable building in Africa[53] figure(3.19) and table(3.6).

In this regard, the building has also achieved the following:

1. It is the first office building in the world to be awarded the Living Building Challenge Water Accreditation for a Medical Facility certification
2. It is the first office building awarded the 6-Star Green Star Medical Suites v1.1 Design certification, the highest Green Star rating ever achieved for a building in South Africa.
3. It scores Net Positive ratings for Waste, Energy, Water and Land-use, and Ecology
4. finally, it was recently awarded the Architecture Award, for the Best office Property in South Africa, at the African Property Awards.

[53] Legaro, "78 Corlett Building," in *MELROSE NORTH* (https://legaro.com: Legaro.com, 2017).

Fig.3.19 : 78 Corlett Drive building[54]

In this design, the form follows energy; in South Africa primarily, the sun is the most crucial driver, controlling heating and light. The building has three-story 7 and the design incorporates strong minimalist geometries, with shading louvers acting as a dynamic facade element and passive shading device[55] figure (3.20),(3.21) and(3.22).

The building includes a central coffee bar in the triple-volume daylit atrium, home to various lively open co-working spaces, cellular offices, and formal meeting rooms. Additional co-working spaces and larger legal offices are located on the first floor to cater to various tenants[56]. The design of the building includes strong minimalist geometries and shading louvers acting as a dynamic facade element and a passive shading machine. Materials used were selected for environmental friendliness and sustainability and meticulously measured to minimize waste. The interior's centered on concrete, warm raw brick, and wood juxtaposed with cool marble and steel.

[54] Matheus Pereira, "78 Corlett Drive Building " in *Daffonchio Architects* (https://www.archdaily.com: archdaily.com, 2023).

[55] solidgreen, "78 Corlett Drive " (www.solidgreen.co.za: solidgreen.com, 2017).

[56] Tanya Simpson, "Adaptive Reuse as a Conduit for Regenerative & Human-Centred Design in Johannesburg," (2020): p 25.

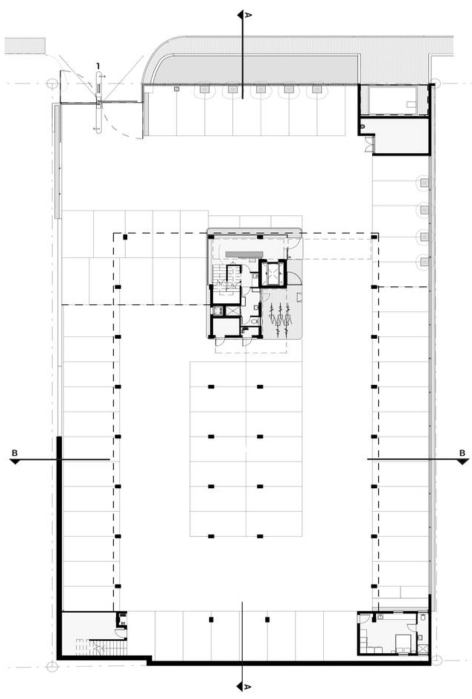

Fig.3.20: 78 Corlett Drive ground floor[57].

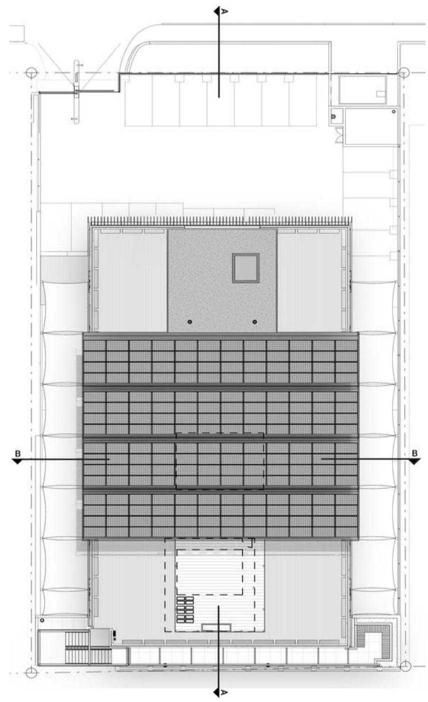

Fig.3.21: 78 Corlett Drive roof plan[58].

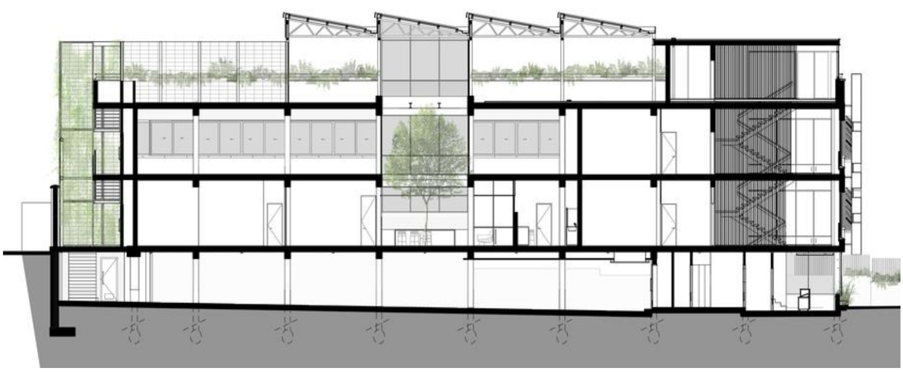

Fig.3.22: Section of 78 Corlett Drive[59].

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57 Matheus Pereira, "78 Corlett Drive Building " in Daffonchio Architects (https://www.archdaily.com: archdaily.com, 2023).

58 Legaro, "78 Corlett Building," in MELROSE NORTH (https://legaro.com: Legaro.com, 2017).

59 Matheus Pereira, "78 Corlett Drive Building " in Daffonchio Architects (https://www.archdaily.com: archdaily.com, 2023).

Table.3.6: 78 Corlett Drive Building Overview[60]

Project Overview			
Location	South Africa	**Architect**	Daffonchio & Associates Architects
Completion date	2017	**Height**	Three stories
Owner/Project manager	Legaro Properties	**Size**	2,167 m2
MEP Engineers and Technology design	Graeme Page Consulting Engineers	**Certifications**	a Zero Carbon (Pilot) Level 1 Certification, a 6-star Green Star Office V1.1 Design, and LBC.

The amount of Portland cement used in concrete was reduced by 40% on average. A 60% recycled content by mass was attained when steel was used. Regarding lumber, 50% of what was used in the building and construction was either Forest Stewardship Council-certified or reused/recycled (by cost).

The price was constantly balanced against the potential benefits. Corlett Drive's development expenses were around 11% higher than conventional construction methods, owing primarily to installing solar panels and shuttering, although the energy savings will offset this over time.

3-13 78 Corlett Drive Design and Living Building Challenge (LBC)

Although the building has not achieved the living certificate it achieves the petal certification which requires the accomplishment of all the Core Imperatives and all Imperatives in the Water, Energy, or Materials Petal in more detail in chapter one[61]. Where the project aims to rather than simply doing ‘less bad’, it could neutralize the impact of developments or even have a net positive impact for able to achieve Net-Positive Ratings in Carbon, Water, Waste, and Ecology[62]. The different

[60] Legaro, "78 Corlett Building," in MELROSE NORTH (https://legaro.com: Legaro.com, 2017).

[61] solidgreen, "78 Corlett Drive " (www.solidgreen.co.za: solidgreen.com, 2017).

[62] Abed Al Waheed Hawila et al., "Plus Energy Building: Operational Definition and Assessment," Energy and Buildings (2022).

systems of architectural and mechanical that the project achieved as follows:

- Major energy-consuming systems are monitored by sub-meters and supplemented with a solar PV array
- The landscaping is waterwise and uses indigenous plants. There's minimal pollution of the natural watercourses
- Paints, carpets, adhesives, sealants, and composite wood products with the lowest- VOC levels were selected
- Water-efficient fittings are used throughout, and there is sub-metering of major water-consuming systems
- Evaporative cooling towers which create a risk of legionella bacteria - were eliminated from the design
- Air-cooled chillers provide cooling. High-performance glazing helps to control the temperature

- Access to natural light is maximized, while the artificial lighting consumes

3-13-1 Indoor Environmental Quality

The design permits a natural visual connection to the external environment for 80% of the Office Useable Area, thus optimizing natural daylight. 100% of the Usable Area is mechanically ventilated and offers abundant good quality outside air, and cooling is delivered to the building by air-cooled chillers, which means the building does not require water to cool.

3-13-2 The Facade of 78 Corlett Drive

The goal was to provide feature lighting to distinguish the façade rather than to illuminate anything." It had to experiment with the strength of the light and tone it down twice to make it muted enough for passers-by to see the lines but not flood the front area with light, It used significant computer modeling with parametric software for simulations, with each facade treated differently depending on direction, protecting against direct sunshine and heat without sacrificing natural light. The north facade is characterized by permanent vertical louvers; the west and east facades are characterized by adjustable exterior blinds with horizontal shade; and the south facade is characterized by a mesh with growing vegetation as shown in figures (3.A), (3.B), (3.C) ,and (3.D).

Fig.3.A: 78 Corlett Drive south elevation[63].

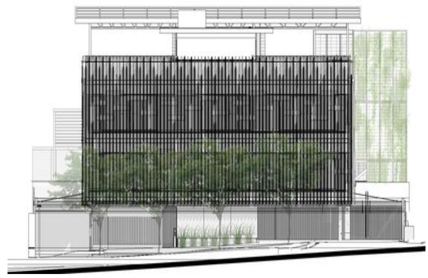

Fig.3.B: 78 Corlett Drive north elevation[64].

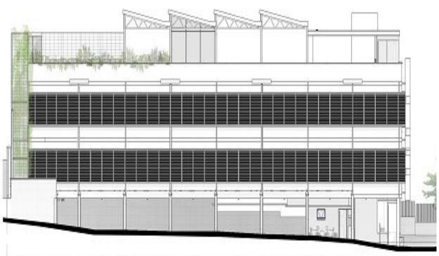

Fig.3.C: 78 Corlett Drive east elevation[65].

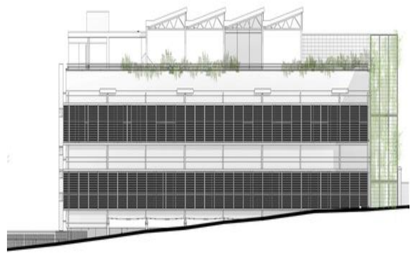

Fig.3.D: 78 Corlett Drive west elevation[66].

3-13-3 The Ventilation.

By showcasing, 100% of the Usable Area is mechanically ventilated and offers adequate good quality outside air. A high level of thermal comfort is achieved by modeling internal operative temperatures and guaranteeing that at least 98% of occupied hours are met. An array of fixed modular shading louvers is a dynamic façade treatment and a highly efficient passive shading system. This was achieved through an interconnected process with lighting & façade specialists and advanced modeling software.

An iconic street presence protects the building occupants from the harsh summer sun while ensuring an almost net-zero wastage through a modular aluminum-clad construction method. In addition, sliding shutters along the adjacent facades create an ever-changing aesthetic, allowing occupants to adjust the amount of natural light, heat, and glare that can

[63] www.archdaily.com, "78 Corlett Drive Building/ Daffonchio Architects."
[64] Ibid.
[65] Ibid.
[66] Ibid.

enter their space[67]. Services and circulation were located in the building's core to reduce the need for long pipes (many of which required insulation), and offices were placed around the perimeter to maximize natural light and ventilation.

3-13-4 Solar PV

The building's peak electrical demand is actively reduced by using a Photovoltaic system that ties into the grid. A 55 kwp photo-voltaic array installation with an annual output of 92 000 kWh is included in 78 Corlett Drive[68].

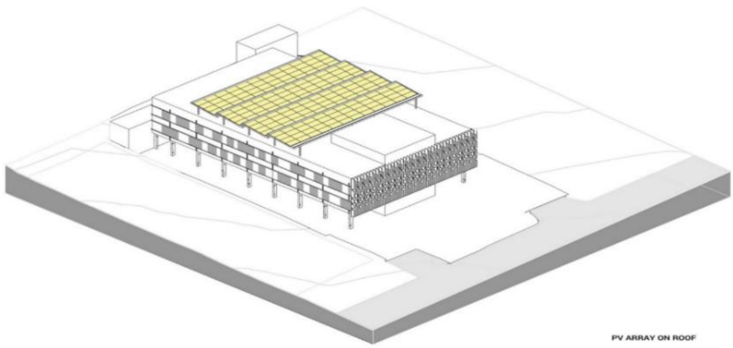

Fig.3.23: PV array on roof of 78 Corlett Drive[69].

3-13-5 Lighting

The design offers a clear visual link to the external environment, for 80% of the office useable area maximizing natural lighting indoors. The project saves energy. This is achieved as the office lighting design achieves an average maintained illuminance level of no more than 400 Lux. The office lighting design ensures the use of artificial lighting with minimal energy consumption as the energy use of 1.5W/m² per 100 Lux was set for the office lighting power densities.[70].

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[67] solidgreen, "78 Corlett Drive " (www.solidgreen.co.za: solidgreen.com, 2017).

[68] Matheus Pereira, "78 Corlett Drive Building " in Daffonchio Architects (https://www.archdaily.com: archdaily.com, 2023).

[69] Matheus Pereira, "78 Corlett Drive Building " in Daffonchio Architects (https://www.archdaily.com: archdaily.com, 2023).

[70] Legaro, "78 Corlett Building," in MELROSE NORTH (https://legaro.com: Legaro.com, 2017).

3-14 Energy performance of 78 Corlett Building

During the design process, an energy model of the building was created, which compared 78 Corlett to a hypothetical building model. An energy model of the building was generated and stages were compared to a notional building model in the design. The building design improved 100% (net zero operating emissions base building) over a SANS 10400 conceptual building. Separate energy sub-meters are provided for lighting and power to monitor energy consumption accurately. The behavior of occupants and users of the building is critical to reducing consumption, and the owners are targeting an overall consumption of 75 kWh/m2/year, far less than the 200 kWh/m2/year SANS10400 XA requirement. As a result, carbon emissions have been reduced to 92 kgCO2/m2/year.

3-15 Conclusion of Chapter Three

The Net-Positive Energy Buildings represent a crucial step toward decarbonizing the building sector, producing more energy than it consumes. That thesis also summarized two office buildings, "Bullitt Center" and the "PAE living building," which achieved the Living Building Challenge certification, which could be a reference repeated in developing countries such as Egypt. Although the two buildings are in the USA, the architectural designs and mechanical techniques used in the "Bullitt Center" and the "PAE living building" suit facilities in different climates. Moreover, the two projects include the following:

- Renewable energy systems, such as PV arrays on-site, and the redundant energy was exported to the network, such as in the "Bullitt Center" building, or using PV arrays on-site and off-site, and the energy redundant was stored in batteries, such as the "PAE Living Building" building.
- HVAC systems such as low-velocity ceiling fans, radiant in-floor cooling, and lighting systems that mainly use daylight and energy-efficient LED lights
- The building envelopes with shading systems and windows with double or triple-glazed, where these techniques reduce energy use and improve the quality of life inside the building.

78 Corlett Drive as the first office building in South Africa to be awarded the Living Building Challenge Petal certification. However, the building has not achieved the seven petals, such as the PAE Living and the

Bullitt Center buildings. Still, it has achieved Net-Positive Energy, making it a unique reference for African buildings.

It was observed that the characteristics of Net-Positive Energy would vary depending on location, climate conditions, and local legislation; so, when establishing a Net-Positive Energy system, it is critical to consider local variables, which vary depending on weather and construction restrictions. Egypt is a developing country undergoing rapid urbanization; the role of Egyptian architects and engineers is to work on implementing regenerative architecture design principles in Egypt buildings and reaching Net-Positive Energy Buildings to get LBC certification, which supports the Egyptian plan to confront climate change.

CHAPTER FOUR

SIMULATION STUDIES FOR IMPLEMENTATION OF NET-POSITIVE ENERGY PROCESS IN EXISTING OFFICE BUILDING

4-1 Introduction

The construction of buildings is one of the most important fields to address energy saving, emission reduction, and global climate change. Due to the current global climate change, immediate action is needed to protect our planet's natural resources. Fossil fuel consumption has increased with the tremendous rise in global energy demand brought on by industrial expansion and population growth. As a result, utilizing fossil fuels causes environmental issues (such as global warming) that are now a global problem. The continued reliance on fossil fuels also leads to an energy crisis because these resources are naturally finite and exhaustible.

Egypt's government is becoming increasingly concerned about rising energy demand. The answer to this problem might be either increased energy supply to meet the ever-increasing demand or increased energy demand efficiency. Improving the efficiency of current energy demand is more important than constantly increasing supply capacity to meet rising future energy demand. In this regard, certain steps have been taken by the Egyptian government and academic and professional disciplines to develop national regulations for energy conservation and rating systems to analyze building energy efficiency.

In light of that, as a part of the thesis to create a detailed strategy to achieve a net positive energy performance level in one of the Egyptian office buildings in Cairo to contribute to achieving the Egyptian goal to face the climate crisis. This chapter mainly focuses on optimizing building envelope design alternatives by integrating various strategies for an office building in Cairo. The impact of these alternatives on the building's cooling and lighting energies was analyzed through an extensive simulation process using eQuest and PVsyst software programs.

4-2 Energy Petal Conditions and Limitations

As mentioned earlier in chapter one, the Living Building Challenge contains seven petals, but we will specialize in the energy petal. Energy Petal plans to achieve (Net-Positive Energy) and develop new renewable energy sources that will enable projects to function year-round in a robust, carbon-free way[1]. The first limitation for achieving net-positive energy

[1] CF Velasco-Fuentes et al., "Shifting the Ownership Paradigm in the Built Environment" (paper presented at the Conference Proceedings, Stream, 2013).

use is renewable sources and safe, and resilient energy infrastructure The energy grid will supply electricity to highly efficient structures that do not contribute to the negative externalities of combustion or fission. Where renewable energy sources are produced on-site or nearby. High-efficiency HVAC, lighting, equipment, appliances, and an adequate control system effectively reduce energy consumption[2]. However, potential energy savings through an optimized design process that reduces the heating and cooling loads typically have more impact than cutting-edge HVAC technologies. Understanding the structure's intended purpose, the requirements for its interior comfort, and examining the natural and environmental resources on the construction site are the first steps in creating a net-positive energy building[3].

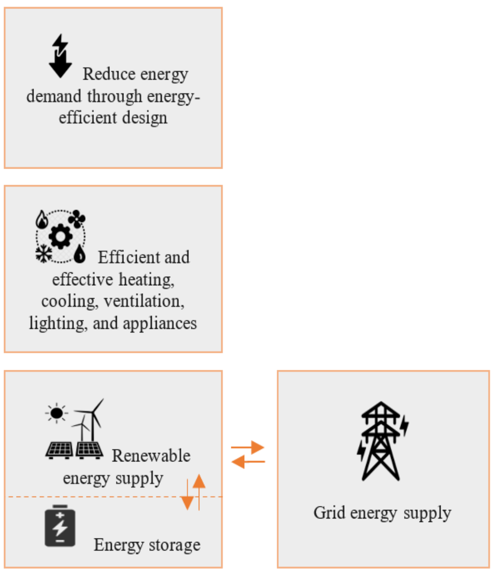

Fig.4. *1*: Overall, of Net-Positive Energy system[4].

The second restriction is that the energy collected on-site more efficiently and assists in the utility grid's gradual phase-out of short-term

[2] Edwin Rodriguez-Ubinas et al., "Passive Design Strategies and Performance of Net Energy Plus Houses," *Energy and buildings* 83 (2014).

[3] RJ Cole and AMS Kashkooli, "Clarifying Net Positive Energy" (paper presented at the CaGBC National Conference and Expo, Vancouver BC, 2013).

[4] Phillip Jones et al., "Energy-Positive House: Performance Assessment through Simulation and Measurement," *Energies* 13, no. 18 (2020).

combustion demands if electricity is stored in the form of batteries or sophisticated materials[5].Treating energy as a valuable resource and reducing energy-related carbon emissions that contribute to climate change are the goals of this imperative. The overall net annual energy consumption of the projects that achieve net-positive energy is decreased (after accounting for on-site renewable power)[6].

4-3 The Methodology of This Chapter

The methodology of the chapter is applied in an office building in Cairo by following a regenerative design process to achieve net-positive energy use as shows in figure (4.2) and that through identing three methods are used to reach the final results, as follows:

4-3-1 Project Boundaries

The project boundaries determine the suitable regenerative solutions for retrofitting an office building and determine suitable renewable resources for the project through three categories:

- Physical Boundary

Refers to the geographic periphery, where it is situated, and where the energy system is physically built.

- Boundary Conditions

Determine the building's purpose and function, space use, temperature condition, comfort level, and the amount of peak hour or peak demand energy.

- Balancing Boundary

Identifying the limit across which the energy carrier is balanced is required to identify the energy types employed and evaluated.

4-3-2 Retrofitting of Building

The different strategies that integrate with buildings to achieve a net-positive energy building as the follows:

- High-performance windows.

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[5] Lavikka et al., *Positive Energy Buildings*.

[6] Hu, "Net-Positive Building and Alternative Energy in an Institutional Environment."

- Thermal Insulations.
- Renewable energy sources.

4-3-3 Impact of alternative using simulation test

Analyzing the impact of alternatives on the building's cooling and lighting energies through an extensive simulation process using e Quest software. Analyzing the PV arrays and batteries on the PVsyst software program.

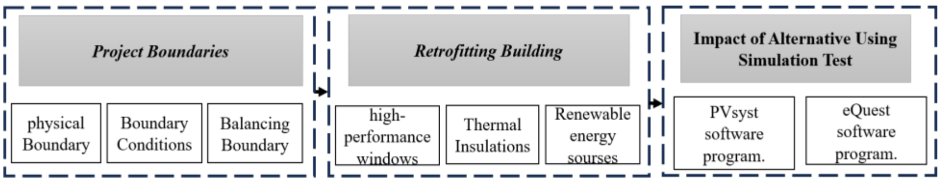


Fig.4.2: The methodology of the chapter.

4-4 The Energy Situation in Cairo

the Egyptian energy sector has been facing enormous challenges recently. Egypt is Africa's most significant oil and natural gas consumer. 20% of Africa's oil consumption and 40% of dry natural gas are consumed in Egypt[7]. Electricity demands are expected to increase at a rate of 6.8% annually over the coming years. The following Figure(4.3) shows that in Electricity Consumption data was reported at 13,909.000 kWh mn in Dec 2023[8].

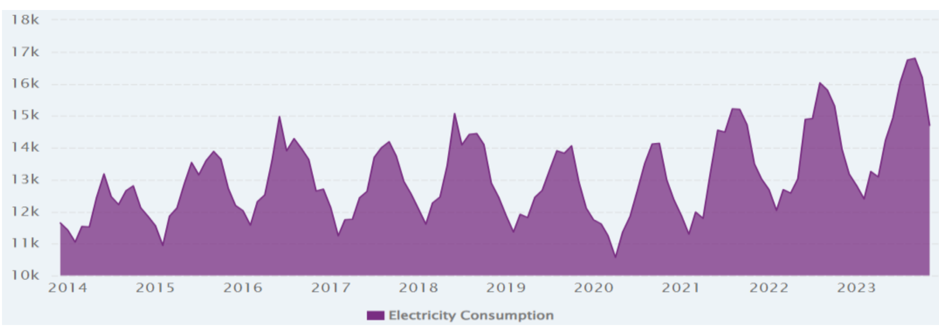


Fig.4.3. Electricity Consumption from 2014 to 2023.[9]

[7] TheWorld Bank, "Country Climate and Development Report."
[8] Minstry of electricity and renewable energy, "Egypt Electricity Consumption," (www.CELCDATA.com2023).
[9] Ibid.

The population of Cairo is 22,624,000 million with a growth rate of 1.99% with energy consumption higher than other Egyptian governorates. While the majority of existing buildings in Cairo are

residential, commercial (such as office buildings), or governmental, the most important non-residential buildings are office buildings, which are increasing noticeably due to Cairo rapid growth as a developing country. It could be seen in new business areas such as New Cairo; thus, the goal of the study explained later is to improve the energy efficiency of office buildings to reduce fossil energy consumption, taking into account Cairo's source of pollution and the obvious threat to the ecosystem[11]. HVAC systems are critical to office buildings' energy efficiency, as HVAC systems consume 55% of the energy in a typical office building Figure (4.4).

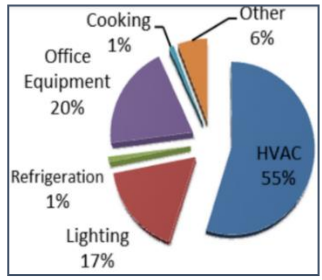


Fig4.4: Typical office building energy consumption by end-use[10].

4-5 Physical Boundaries of the Office Building

In this stage, identifing the office building boundary through the geographic periphery and climate determining.

4-5-1The Geographic

The office building is Located in Cairo and is characterized by a hot, arid climate region with high solar radiation intensity and dominant cooling loads. The office is between 31.33° N and 22 °N and 26 and 35 °E longitudes[12] figure(4.5). It consists mainly of desert. The office building the thesis will discuss is located southwest of New Cairo. It is one of the office buildings from Bavaria Town Compound

[10] Ghaid Ateek, "Energy-Efficient Building Design Guide," (2020).
[11] AbdelAzim, Ibrahim, and Aboul-Zahab, "Development of an Energy Efficiency Rating System for Existing Buildings Using Analytic Hierarchy Process–the Case of Egypt."
[12] TheWorld Bank, "Country Climate and Development Report."

Fig.4.5: The location of the office building. [13]

4-5-2 Climate Data

Cairo has a desert-dominated environment that is hot and dry. The country experiences a pleasant winter and a hot, dry summer (May to September). Seasonal variations in daytime temperatures range from an average 14°C minimum in the winter (November to April) to an average 30°C maximum in the summer (May to October). Cairo governorate experiences humidity throughout the summer[14].

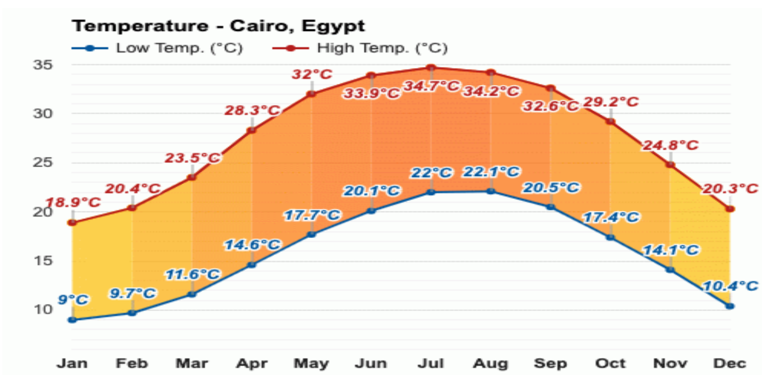


Fig.4.6: Cairo's average monthly temperature (2023). [15]

Yet, it only experiences a little over one centimeter of precipitation annually. Only a few drops of rainfall in the areas south of Cairo, yet they might suddenly encounter major precipitation events that cause flash

[13] https://earth.google.com, (2023).

[14] World Health Organization, "Trends in Maternal Mortality 2000 to 2020: Estimates by Who, Unicef, Unfpa, World Bank Group and Undesa/Population Division: Executive Summary," (2023).

[15] Wather Atlas, "Climate and Monthly Weather Forecast Cairo, Egypt," (https://www.weather-atlas.com: Wather Atlas.com, 2023).

floods. Figure(4.6) shows the data analysis of Cario's average monthly temperature ranges from 37°C in July to 22°C in January, with a mean annual temperature of 26°C.

The average precipitation per year is 33.3 mm, with the wettest months being December through February and the driest months almost the entire year[16].

4-6 Boundary Conditions

In this stage, determine the building's purpose and function, space use as following.

4-6-1 The Office Building Overview

The office building's total area is 950 m2, consisting of eleven floors with a garage on the basement floor and shops on the ground floor as shows in figure (4.7).

Fig.4.7: The façade of the office building

The Convention and Meeting Center, Lobbies (Main Entry and Assembly), Dining Area, Corridor, Kitchen, Food Preparation Spaces, and Restrooms connected to building services are all part of the structure. A central mechanical ventilation system is used in the building; heating, cooling, and ventilation systems acclimatize the indoor atmosphere and maintain indoor air quality as shown in the office plans in figure (4.8) and (4.9). According to the weather, the cooling system is used primarily in the summer; it is an air-cooled liquid chiller with a heat recovery system that runs on electricity, while heating systems are not needed in the winter. For

[16] Henrique Morgado Simões, "Egypt's Climate Change Policies State of Play Ahead of Cop27," ed. Branislav Stanicek (European Parliamentary Research Service, 2022).

workplaces, the comfort temperature range is around 22 °C, while for circulation spaces, it is around 20 °C.

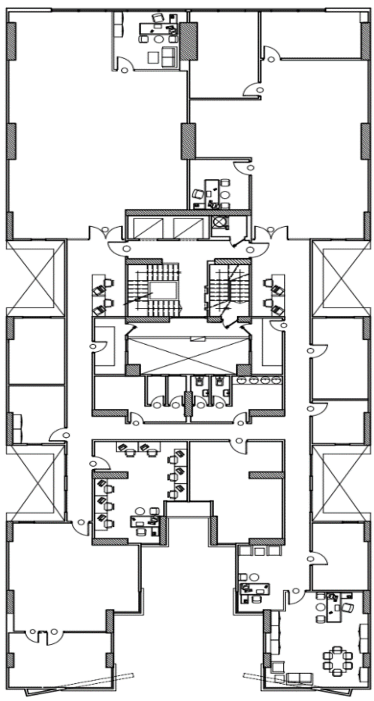


Fig.4.8: The typical plan

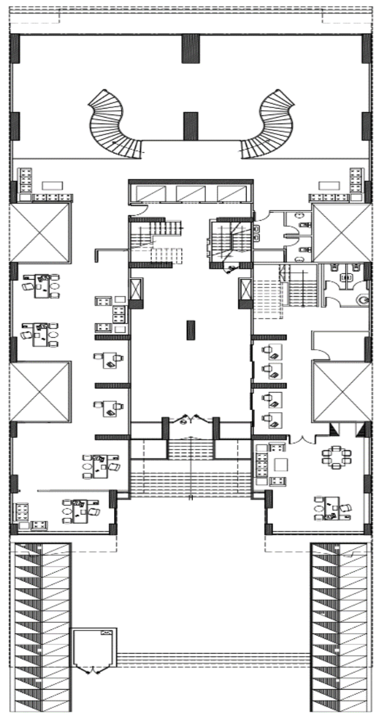


Fig.4.9: Ground Floor

Table.4.1: The Office building overviews

Project Overview			
Location	South of Cairo	**Site area**	950 m2
Function	Office Building	**No of Floors**	Eleven stories
Owner	Meamar El morshedy	**Floor Height**	2.8 m
Visitors in the day	400	**The working hours**	9 am to 5 pm
Closing Days	Is closed on Friday and Saturday	**Facades**	constructed with blue single-glazed reflecting glazing curtain walls with aluminum frames.

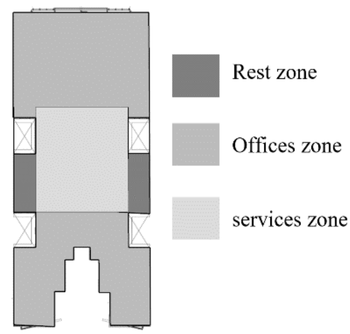


Fig.4.10: Functional elements of the office building

The building has 400 visitors and operates on a twelve-hour basis during the week; the facility's usual working hours are from 9 am. to 5 pm. on weekdays and is closed on Friday and Saturday except for the control rooms, which are operational 24 hours a day, seven days a week as shown in table (4.1). The main construction of the building is built of reinforced concrete. Elevations are mostly constructed with blue single-glazed reflecting glazing curtain walls with aluminum frames as shown in figure (4.11) and (4.12). The interior space layout is a plan divided into office rooms with wings connected by two main corridors, and the offices are positioned on the building's periphery with subsidiary corridors as shown in figure (4.10).

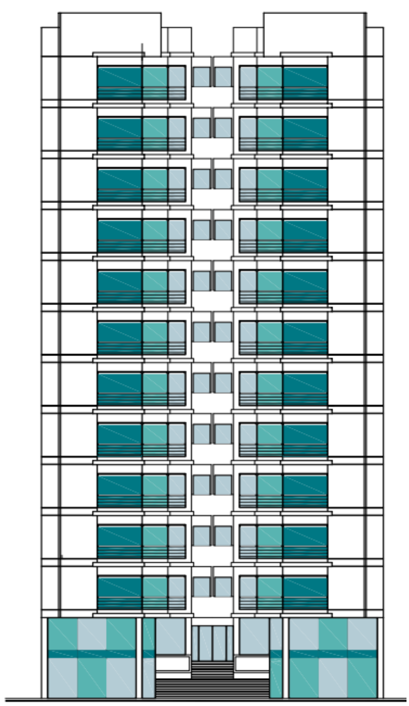


Fig.4.11: The south elevation

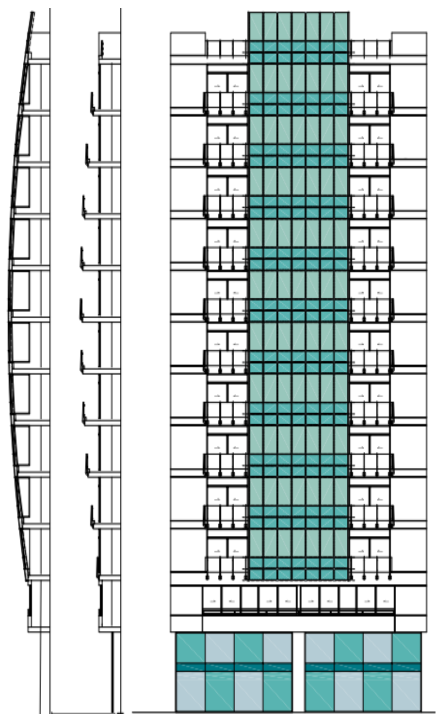


Fig.4.12: The north elevation

The building is a rectangle of dimensions 47.3m x 19.9m, the floor height is 2.8m, Externally, all elevations are unshaded with a considerable amount of fixed curtain walls, resulting in heat gains and an increase in the use of mechanical ventilation. Tinted glazing results in inefficient daylighting, as an inner set of offices only receives very poor daylight from the skylight as they overlook the court in the center of the plan; internal shading devices (blinds) are installed in all offices, operable from within each office, and are frequently used by occupants to avoid in sun subject façades. The external walls are not insulated; they comprise a 25 cm brick wall and 2cm inside and exterior paint, for a total U-value of 1.5 W/m2 K. Furthermore, natural ventilation is not exploited because the building uses mechanical ventilation.

4-6-2 Building Orientation

Building orientation is one of the architectural planning criteria that influences the heat and energy performance of structures. The daylight situation is affected not just by latitude but also by a building's orientation, with each facade or material requiring a particular design importance. As a result, daylight and architectural design methods are inextricably linked in figure (4.7).

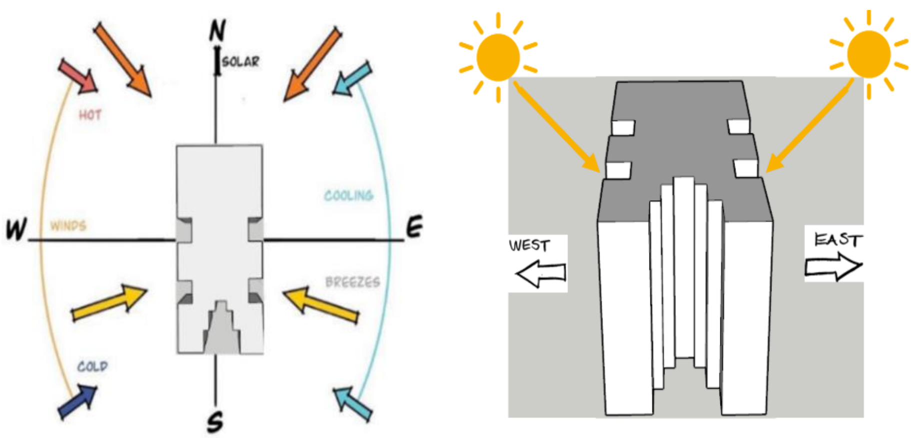
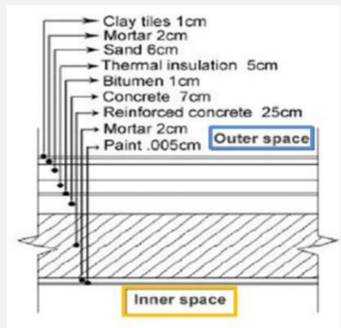
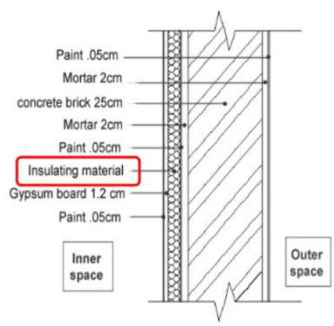
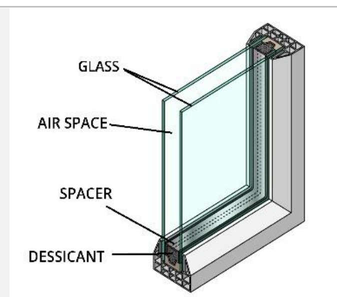


Fig 4.13: Office building orientation.

4-7 Retrofitting office Buildings

This stage will discuss different architectural strategies to reach a net-positive energy building, where it will integrate the strategy with an existing office building envelope in Cairo. The process, of this could allow buildings to reach a very high level of performance and reduce operating costs at minimal extra capital cost. In table (4.2) shows alterations to the office building.

Table 4.2 Possible Alterations to the Building.

Possible Retrofit Strategies	Description		Details
Roof Insulation	An insulating layer comprising an expanded polystyrene sheet coated on both sides with cement mortar and fiberglass mesh. This retrofitting technique is selected because it is commonly used in the Egyptian building industry, which makes it suitable for application.	U-value=0.158 W/m2K	
Wall Insulation	Insulation polystyrene 0.05 m was added to the currently constructed walls. EPS is an inorganic and rot-proof insulation material. In addition to being moisture resistant, EPS insulation boards are highly energy efficient, lightweight, easy to handle, and stable long-term insulation material.	U-value=0.148 W/m2K	
Retrofitting of Windows	Retrofitting techniques of openings aim to decrease the solar heat gain coefficient (SHGC) of all window glazing by implementing the following type of glazing. Double-glass windows replace single-glass windows (two 6 mm glass with 6 mm distance)	SHGC=0.27	

4-8 Evaluation of the Effects by using Simulation Software Software programs

The thesis used the "e QUEST" software for energy performance evaluation and implementing energy-efficient improvement strategies as shown in figure (4.14). e QUEST; It is a building energy analysis platform created to comprehensively analyze building construction technology

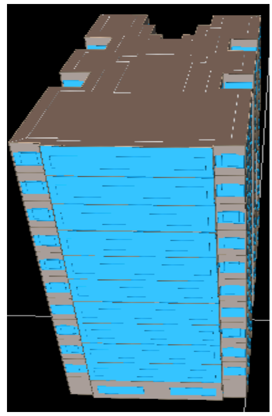


Fig.4.14: Building model

using today's most advanced building energy simulation techniques. E QUEST can be used at all stages of a building simulation's development, including its early design and final construction stages. It has also been used in many projects to achieve net-positive energy use.

The e QUEST program is used in this thesis to evaluate the energy consumption performance of the proposed office building project in Cairo, Egypt, and calculate annual heating or cooling demands and total energy use intensity. Table (4.3) shows the structure of the e QUEST simulation software testing process with the whole project data and its primary and alternate schedules, as mentioned below.

Table 4.3: Checklists for e-QUEST simulation software with its primary and alternate schedules, based on (e-QUEST software)

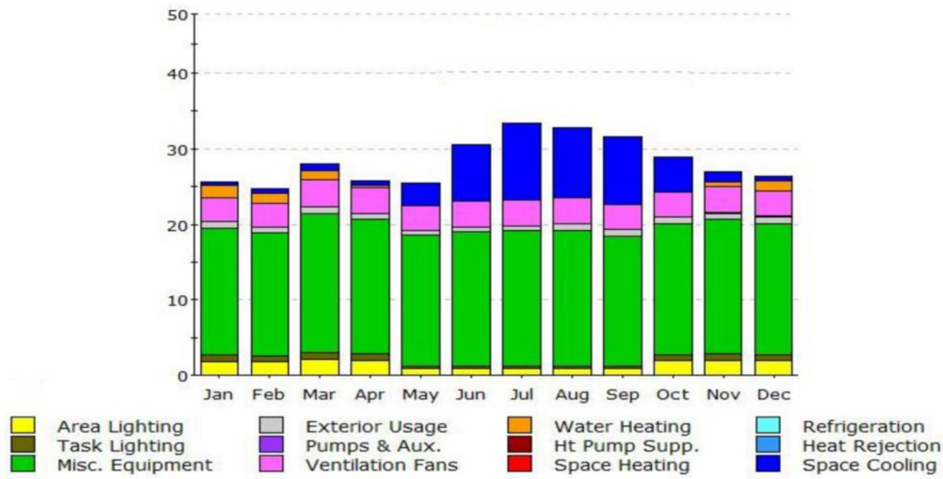
e-QUEST Checklists					
General project information		Daylight zoning and activity areas allocation		Heating and cooling primary equipment	
Building footprint		HVAC system hot or cold deck resets		Energy-efficiency measure	
Building envelope and interior constructions		HVAC system definitions and zones for temperatures and air flows		Chilled and hot water systems control	
Exterior windows, doors and shades		Occupied and unoccupied Loads by Activity Area		Water-source heat pump equipment	
Roof skylights		HVAC system fans equipment		DWH equipment	

4-9 Numerical Simulation and Analytical Calculations

The office building base case and the new proposed building with NPEB standards were verified by energy modeling simulation using the eQUEST table (4.4). Additionally, eQUEST calculations and final results for the two projects' verification were summarized and submitted with the following calculations shown in Figures (4.17 and 4.18).

Table 4.4: U-values and SHGC calculations of the office building envelope for base-case building and new proposed building with NPEB standards.

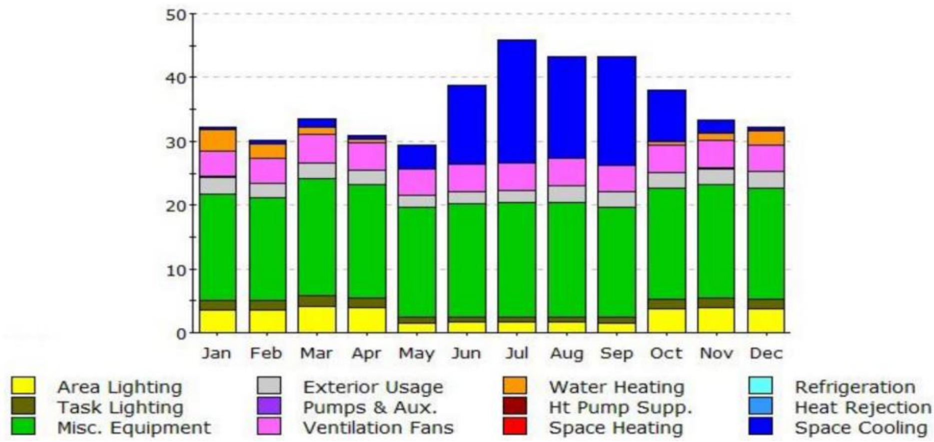
Building envelope	Base-case building	Proposed building with NPEB standards
External wall	**U-value=1.6** W/m2K	**U-value=0.143** W/m2K
Roof	**U-value=1.2** W/m2K	**U-value=0.158** W/m2K
Windows	**Single glass SHGC=0.43**	**Double glass SHGC=0.27**



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.36	0.58	0.90	0.57	3.02	7.37	10.14	9.26	9.00	4.52	1.36	0.53	47.64
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	1.70	1.42	1.14	0.31	0.01	-	-	-	0.01	0.03	0.57	1.42	6.60
Vent. Fans	3.16	3.16	3.63	3.47	3.31	3.47	3.47	3.47	3.31	3.31	3.47	3.31	40.57
Pumps & Aux.	0.04	0.02	0.02	0.02	0.00	-	-	-	-	0.00	0.04	0.04	0.20
Ext. Usage	0.88	0.71	0.79	0.76	0.63	0.61	0.63	0.88	0.86	0.88	0.86	0.88	9.38
Misc. Equip.	16.80	16.28	18.51	17.77	17.35	17.79	17.94	17.93	17.23	17.36	17.77	17.40	210.14
Task Lights	0.81	0.81	0.93	0.89	0.27	0.29	0.29	0.29	0.27	0.85	0.89	0.85	7.42
Area Lights	1.82	1.79	2.05	1.96	0.92	0.96	0.96	0.96	0.94	1.89	1.96	1.89	18.12
Total	25.58	24.77	27.97	25.77	25.52	30.49	33.44	32.79	31.62	28.85	26.92	26.34	340.06

Fig.4.15: Energy consumption calculations worksheet using e-QUEST software for the base case.



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.43	0.60	1.28	0.48	3.73	12.28	19.24	15.96	16.87	8.06	1.97	0.51	81.40
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	3.41	2.27	1.14	0.57	0.01	-	-	-	0.01	0.57	1.14	2.27	11.37
Vent. Fans	3.96	3.96	4.55	4.35	4.15	4.35	4.35	4.35	4.15	4.15	4.35	4.15	50.84
Pumps & Aux.	0.04	0.02	0.02	0.02	0.00	-	-	-	-	0.00	0.04	0.04	0.20
Ext. Usage	2.60	2.09	2.31	2.24	1.86	1.80	1.86	2.60	2.52	2.60	2.52	2.60	27.60
Misc. Equip.	16.79	16.26	18.51	17.74	17.35	17.79	17.93	17.93	17.23	17.33	17.76	17.42	210.04
Task Lights	1.46	1.46	1.68	1.60	0.83	0.86	0.86	0.86	0.82	1.53	1.60	1.53	15.09
Area Lights	3.55	3.52	4.04	3.87	1.54	1.61	1.60	1.60	1.57	3.71	3.87	3.71	34.19
Total	32.23	30.18	33.52	30.87	29.47	38.70	45.84	43.31	43.17	37.95	33.25	32.24	430.73

Fig.4.16: Energy consumption calculations worksheet using e-QUEST software for a new proposed office building.

According to the comparison of electric consumption between the base-case building and the proposed building with Net-Positive Energy, the 21% reduction in energy use in the newly planned office building is shown in Figure (4.17).

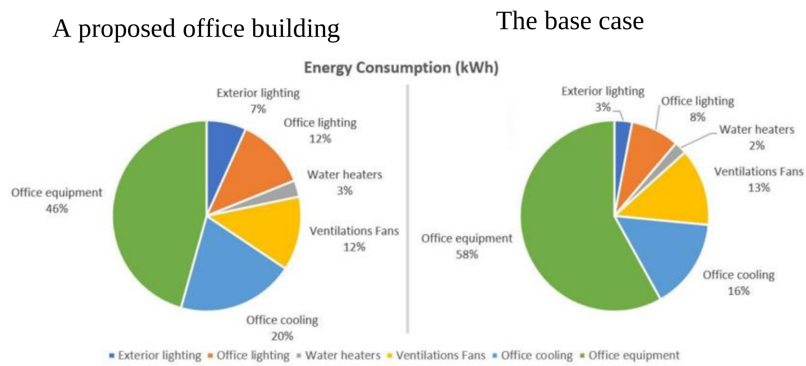


Fig.4.17: Comparison of office building energy consumption between base-case building and proposed building.

4-10 Renewable Energy Sources

The base office building has no renewable energy sources, and it is dependent on the grid for all energy consumption. On retrofitting the building, it installing PV arrays on the roof and also battery storage. In this part, PVsyst software was used to give a detailed contextual menu that explains the procedures and models used and offers a user-friendly approach with a guide to developing a project as in table (4.5).

Table 4.5: Characteristics of Photovoltaic Panels

Collector Plane Orientation		Tilt	30°	Azimuth	0°
Models used		Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon		Free Horizon			
Near Shadings		No Shadings			
PV Array Characteristics					
PV module	Si-mono	Model	**STP 265S-20/Wd+**		
Original PVsyst database		Manufacturer	Suntech		
Number of PV modules		In series	14 modules	In parallel	8 strings
Total number of PV modules		Nb. modules	112	Unit Nom. Power	265 Wp
Array global power		Nominal (STC)	**29.68 kWp**	At operating cond.	26.41 kWp (50°C)
Array operating characteristics (50°C)		U mpp	380 V	I mpp	69 A
Total area		Module area	**182 m²**	Cell area	163 m²
Inverter		Model	**UNO-3.0-TL-OUTD**		
Original PVsyst database		Manufacturer	ABB		
Characteristics		Operating Voltage	80-580 V	Unit Nom. Power	3.00 kWac
Inverter pack		Nb. of inverters	8 units	Total Power	24 kWac
				Pnom ratio	1.24
PV Array loss factors					
Thermal Loss factor		Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss		Global array res.	93 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss				Loss Fraction	-1.3 %
Module Mismatch Losses				Loss Fraction	1.0 % at MPP
Incidence effect, ASHRAE parametrization		IAM =	1 - bo (1/cos i - 1)	bo Param.	0.05

PV arrays were installed on the surface in parallel as shown in figure (4.18), and through the results of the program, the panels that would be produced 50.94Mwh/year.

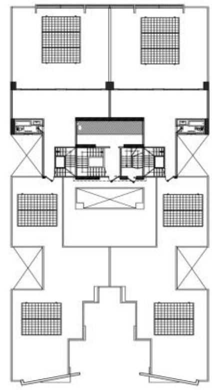


Fig.4.18: PV arrays on the roof of the retrofitting office building

4-11 Storage and Renewable Energy

The thesis chose a typical lithium-ion battery courtesy of the LG figure (4.21). These batteries charge and discharge by the movement of lithium ions between the electrodes.

Originally found popularity in the portable consumer and business electronic products market. Lighter, having between two, and five times better storage capacity in terms of the weight of the battery than lead-acid types. Between 10 and 20 times more charge-discharge cycles than lead-acid types, making them more suitable for frequent charge-discharge uses associated with load profile shifting and domestic generation technologies such as solar PV.

Fig4.19: Lithium-ion battery courtesy of LG.17

4-12 Models of Batteries and Techniques

With PVsyst, grid-connected system simulation is an established and popular application. Because many dispatch tactics are feasible based on the goals of the system owner, battery storage is added to the simulation. There are three different dispatch strategies in the present tool as follows:

4-12-1 Self-Consumption

The goal of the self-consumption dispatch approach is to exchange as little power as possible with the grid as shown in figure (4.20). It accomplishes this by giving battery charging precedence over grid infusion. During periods of low PV generation, the stored energy is then used to cover a specified load profile. The battery solely receives power

[17] Authority, *Energy Storage Systems*.

from the PV system and releases it in response to load demand; it has no communication with the grid.

Fig.4. 20: Self-Consumption strategy

4-12-2 weak grid islanding

The goal of weak grid islanding is to bridge grid interruptions by using battery storage as a backup as shown in figure (4.21). The battery is also utilized in this mode to cover a self-consumption load profile, but during normal operation, its discharge level is restricted to a level that permits the load profile to be maintained in the event of a grid outage. The battery is permitted to discharge to a lower level during a grid outage. The option to inject the PV system into the grid or not is up to the user in these scenarios. But it's not permitted to charge or discharge the battery from or to the grid.

Fig.4. 21: weak grid islanding strategy.

4-12-3 Peak Shaving

Peak shaving is a practice designed to store excess PV generation and then inject it back into the grid during times of low generation. In this manner, energy that was curtailed during the generating peak is recovered and reinjected outside of peak times. In this mode, the PV generation surpasses a certain injection limit level, which charges the battery. When the PV generation goes below this threshold, the battery discharges begin. Grid power is never used to charge the battery (Figure 4.22). This tactic offers two advantages. First, owners of PV plants can recoup the benefits of overproduction of PV energy; second, the grid operator can easily control the production of renewable energy.

Fig.4. 22: Peak shaving strategy

4-13 Numerical Simulation and Analytical Calculation for Battery Storage

The characteristics of the storage battery in PVsyst software were chosen peak sheaving system and LG battery with 1234V and stored energy 294.7KWh, as shown in Table (4.7).

Table 4.6: Characteristics of battery

Battery	Model	**Rack JH4 SR32_4P**		
	Manufacturer	LG Chem		
Battery Pack Characteristics	Nb. of units	1		
	Voltage	1234 V	Nominal Capacity	296 Ah (C10)
	Discharging min. SOC	20.0 %	Stored energy	294.7 kWh
	Temperature	Fixed (20°C)		
Battery input charger	Model	Generic		
	Max. charging power	84.0 kWdc	Max./ Euro efficiency	97.0/95.0 %
Battery to Grid inverter	Model	Generic		
	Max. discharging power	64.0 kWac	Max./ Euro efficiency	97.0/95.0 %

4-14 Conclusion of Chapter Four

This chapter determines whether the desired performance can be met with the adjustments that can be done to make a Cairo office building a Net-Positive Energy Building. The study's solutions recommend incorporating a new component rather than modifying the complete building component layer. The thermal comfort conditions of the building's outer elements were changed, and alternative energy sources were integrated. The energy performances for operation have been assessed using these variables. Furthermore, the baseline energy performance data for the structure and the data produced after the improvements were compared as follows. When "Baseline" and improvement scenarios are compared, a rise in energy performance is observed with a decrease in energy consumption, according to statistics, in pace with increased electricity demand. Integrating PV panels inside the structure may generate 297.7mwh per year and store it in batteries.

Conclusions

- Conclusions
- Discussion
- Recommendations

Conclusions

The thesis submitted the concept of a regenerative design as a new mindset for responding to the climate changes encountered by developing countries such as Egypt and then, the study specialized in reaching the office building in Cairo to Net-Positive Energy as it is considered one of the applications the regenerative approach. The built environment could significantly enhance the surrounding urban environment's sustainability by activating the regenerative approach as a paradigm for sustainable and environmentally responsible design. The thesis discussed essential points as follows: A regenerative design represents buildings intended to enhance, restore, and improve the surrounding natural environment by aiming to leave a positive impact instead of a harm reduction.

- Regenerative buildings could effectively solve current environmental problems as they go beyond sustainable building levels.

- The Living Building Challenge (LBC) tool is considered more comprehensive for implementing regenerative design principles. Its mission is to promote a fundamental systemic reform of the construction industry, transforming it into regenerative systems.

- The Net-Positive Energy Buildings represent a crucial step toward decarbonizing the building sector, producing more energy than it consumes.

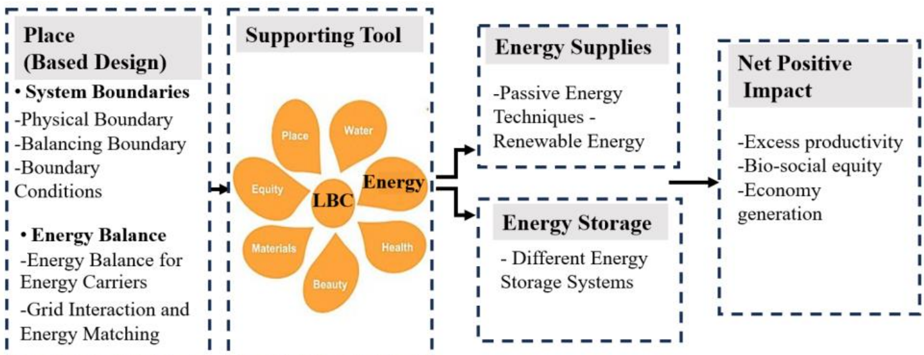
- The parameters of the Net-Positive Energy system would change depending on the location, climate conditions, and local policies.

The thesis also summarized three office buildings, "Bullitt Center", the "PAE living building," and 78 Corlett Drive which achieved the Living Building Challenge certification, which could be a reference repeated in developing countries such as Egypt. Although the first buildings are in the USA, the architectural designs and mechanical techniques used in the "Bullitt Center" and the "PAE Living Building" suit facilities in different climates. Moreover, the two projects include the following:

- Renewable energy systems, such as PV arrays on-site, and the redundant energy was exported to the network, such as in the "Bullitt Center" building, or using PV arrays on-site and off-site, and the energy redundant was stored in batteries, such as the "PAE Living Building" building.

- HVAC systems such as low-velocity ceiling fans, radiant in-floor cooling, and lighting systems that mainly use daylight and energy-efficient LED lights
- The building envelopes with shading systems and windows with double or triple-glazed, where these techniques reduce energy use and improve the quality of life inside the building.

78 Corlett Drive building as the first office building in South Africa to be awarded the Living Building Challenge Petal certification. However, the building has not achieved the seven petals, such as the PAE Living and the Bullitt Center buildings. Still, it has achieved Net-Positive Energy, making it a unique reference for African buildings. Egypt is a developing country undergoing rapid urbanization; the role of Egyptian architects and engineers is to work on implementing regenerative architectural design principles in Egyptian buildings and reaching Net-Positive Energy Buildings to get LBC certification, which supports the Egyptian plan to confront climate change.



DISCUSSION

The main results that can be drawn from the conducted study are the following:

- Improving the energy efficiency of buildings and reducing related CO_2 emissions is one of the energy and climate strategies spearheaded when targeting to mitigate climate change.

- Designers went through many stages of development to aim for less harm to the environment and human health besides the efficient use of resources.

- Experts are developing new design and construction support tools and technological solutions to implement regenerative design principles to support a regenerative worldview.

- The term "regenerative design" was coined to describe a philosophy that views all human activities and environmental systems in a broader context than the traditional idea of sustainability.

- A regenerative design sees humans participating as co-creative members of nature and its co-evolutionary processes.

- The regenerative approach is considered the highest architectural design concept regarding positive productivity toward the environment.

- Positive energy building (PEB) is used to collectively address climate change, and increase energy efficiency and renewable energy share in the buildings.

Recommendations

This thesis aims to provide a comprehensive vision of regenerative design and how to reach Net-Positive Energy Buildings to counter climate changes. Based on the literature review and case studies, a few necessary actions were recommended by the study to be considered by Egyptian authorities, field experts in renewable energy, and faculty for designing and implementing Net-Positive Energy buildings in Egypt. The following are some recommendations that would contribute to the upgrading of Egyptian environmental architecture:

<u>Recommendation for Government and Public Authorities</u>

• Set broad goals for Net-Positive Energy buildings implementation in cooperation with manufacturers and set a time frame for reaching these goals.

• Performing training courses for engineers on Regenerative Design, its principles and characteristics, and how to achieve Living Building Challenge certification.

• Raising awareness and advertising the concept of regenerative design and its applications, including Net-Positive Energy Buildings, through publishing in specialized scientific and architectural fields, research, and architectural studies.

• Attempting to benefit from scientific expertise in the regenerative design field to benefit from previous experiences and start from where others left off.

Recommendation for Educational Centers and Universities

• Inclusion of the concept of regenerative design and the study of its characteristics within the curricula of universities and scientific engineering institutions, whether governmental or private, in the pre-and post-graduation stages, as this plays a significant role in creating a generation of architects familiar with these concepts and strategies and everything new.

• Forming an integrated research team covering all disciplines related to renewable architecture to carry out a series of research and specialized studies to examine the possibility and ways of applying these strategies to the current reality and to conduct training research for engineers and technicians to prepare technical cadres that will implement, operate and maintain this type of buildings

• Promote Net-Positive Energy buildings' practical experience through intensive training.

• Use Net-Positive Energy applications in universities and engineering centers to train students and engineers using energy simulation to evaluate building performance to produce more than it uses.

• Collaboration and communication between engineering sectors and stakeholders should occur through shared projects.

Recommendation for Further Researches

• There is a need for additional research to direct more attention to regenerative design standards and study their impact if implemented in buildings in Egypt.

• As well as communication with Egyptian government authorities to form a complete perspective on regenerative standards and requirements, in addition, to contact with Egyptian engineering firms to achieve Net-Positive Energy performance.

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Appendix

1-Support Tools for Regenerative Design and Development

Regenerative design and development is a new field that treats the current sustainability paradigm. At the same time, the practitioners have already known that limiting the adverse effects of human interventions on nature is no longer sufficient.

Experts are developing new design and construction support tools and technological solutions to implement regenerative design principles to support this change toward a regenerative worldview. Based on the above-listed criterion, five of the most popular and widespread rating tools in the construction industry were selected: LEED, BREEAM, DGNB, WELL, and Living Building Challenge (LBC).

Where these tools emerge to depict critical characteristics and attributes and assist practitioners, designers, and stakeholders, emerging design support tools bridge the regenerative design and development theory to simplify the theoretical underpinnings and process. However, the change in current practice can take time and effort, so it is essential to have a tool or guide and metrics/indicators to understand and apply regenerative approaches. Therefore, the comparison explores the tools and the most influential indicator stations to determine existing gaps and recommendations for evolution toward the renewal goals.

The following will discuss the tools individually, the definition of each tool through where and when they were first published, and the requirements scale required for building.

BREEAM: The British Building Research Establishment Environmental Assessment Method, First published in the U.K. in 1990. is now one of the most extensively used tools worldwide, mainly throughout Europe. It has since been applied in more than 70 countries. The most current international version, BREEAM International, for New Construction 2016, has been launched to certify projects worldwide. The requirements for the building scale are in the following topics: Management, Health, Well-being, Energy, Transport, Water, Materials, Waste, Land use and ecology, Pollution, and Innovation.

LEED: The tool that USGBC developed is an abbreviation for Leadership in Energy and Environmental Design. It is a voluntary and market-driven rating tool measuring the sustainability of building construction projects. The first version of LEED was developed in 1998 and has become one of the most internationally widespread sustainability assessment tools. The current version (v4) has been in use since 2014. It contains mandatory and optional requirements on nine topics: Integrative

Design, Sustainable sites, Location and Transportation, Water Efficiency, Energy and Atmosphere, Indoor Environmental Quality, Materials and Resources, Innovations, and Regional Priorities.

DGNB: The German DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) system. is another variant of the widespread sustainability rating tools with a lifecycle-based approach, where the latest international version of the assessment system was published in 2018. This version applies to new construction projects with different credit weighting for other functions. In this study, the office function was selected as it is the most used system version for assessment tools.

WELL: The WELL standard was published by the International WELL Building Institute in 2014. The current version is the WELL v2, which has been applicable as a pilot system since 2018. The WELL certification defines requirements for more healthy buildings that improve users' well-being and productivity in 11 topics: Air, Water, nourishment, Light, Movement, Thermal Comfort, Sound, Materials, Mind, Community, and Innovation. In addition, the rating tool includes mandatory and optional requirements that are needed to reach the different certification levels.

LBC: the observation of The Living Building Challenge standard was first released in 2006 by the Living Future Institute. The primary goal of LBC is to eliminate any negative impact a building might have on global health. The standard defines 20 challenges (each with the same weight) in seven topics. In this study, version 4.0 of LBC was assessed.

1-2The Methodology of Comparison

For comparison between tools, it used the "Rethinking Sustainability Towards a Regenerative Economy" book as a reference, the methodology of comparing the tools through the following:

1-Determination of regenerative goals and their thresholds (their required level of performance). providing the basis for assessing how regenerative purposes are covered in the selected rating tools.

2- Assessment of each point in the selected tools by the following aspects:

- Related regenerative topic

-A related aspect of the relevant topic (see Fig.1.11)

4-Type of connection to the case:

-Direct: Adherence to the indicator's requirements directly advances a goal identified in the pertinent regenerative architecture issue.

-Indirect: Complying with the requirements of the indicator does not directly advance its purpose, but the solution put into practice has an indirect impact on it.

3. Assessment of the level of coverage of regenerative topics:

• **Quantitative assessment**: the percentage rate of points covering each regenerative topic is determined so that each system can determine relative importance. The results are shown as ratios of a contingent total score to compare the different assessment tools.

Qualitative assessment: the coverage of each regenerative topic is assessed by the following qualities (see Fig.A.A).

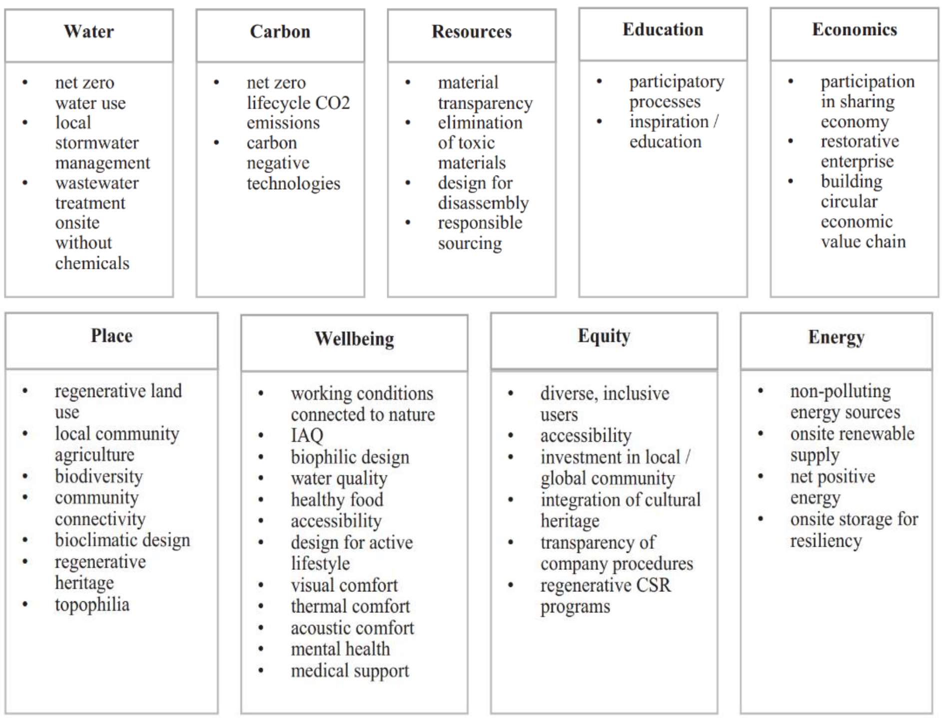

Fig.A.A: The regenerative goals are defined for the nine topics.

1-3Results of comparing

The results of the quantitative and qualitative assessments showed that, on average, the well-being-related aspects of regenerative architecture included the highest weight in the five assessment tools. However, it also indicates that education-and economic-and carbon-related issues are underrepresented. It noted that the carbon category coverage is indirectly improved, as the energy and some of the resources-related requirements contribute toward net positive carbon goals. In addition, the analysis of the five tools selected showed that the typology of the tools, based on their purpose (sustainability, wellness, and regenerative systems), showed that LBC is much more comprehensive in incorporating the identified aspects and handling the majority of issues highlighted in the academic literature.

On the other hand, WELL focuses on providing healthy buildings for occupants while embracing the widest variety of practical health-related regeneration elements.

The LEED, BREEAM, and DGNB rating tools, primarily geared toward sustainability, are located in the middle and offer adequate coverage of the regenerative goals that emerged from traditional sustainability plans. However, they have a limited range of education and equity-related topics and thresholds.

LEED system is the worst among the three sustainability-focused systems because it needs to set high standards in the other areas and address fairness and education.

The results show that the LBC system covers all categories equally. The subjects of resources, location, and well-being have the most significant percentage of credits in this system. This assessment shows how these nine topics are incorporated into the selected tools for evaluating regenerative architecture. Table(A.A) includes the results of the evaluation. It shows that three of the nine issues are covered at least partially by all these rating tools.

Regarding the alignment with regenerative objectives, LBC concentrates on four themes that will have favorable effects for all regenerative purposes (place, energy, water, and carbon). The standard may be higher where LBC covers all concerns in the resource and education areas. Moreover, table (B.B) further demonstrates that the system only partially fulfills all of the aims in the Well-being and Equity categories, with the Economics category receiving the least attention.

Table. A.A: Results of the qualitative assessment of the coverage of regenerative goals.

Grey: no aspects are covered; yellow: some parts are covered indirectly; light green: some parts are covered directly; green: all aspects are covered; dark green: all aspects are covered, regenerative goals

	Place	Energy	Water	Wellbeing	Carbon	Resource	Equality	Education	Economics
BREEAM	×	×	×	×	××	×	×	×	×
LEED	×	×	×	×	××	×	-	-	0
DGNB	×	×	×	×	×	××	×	××	
WELL	×	-	-	×××	-	×	×	××	-
LBC	×××	×××	×××	×	×××	××	×	××	0

Table.B.B: Results of the LBC assessment about covering regenerative goals.

Covered	3	3						
Resources	material transparency	elimination of toxic materials	design for disassembly	responsible sourcing				xx
Covered	3	3	2	3				
Equity	diverse, inclusive users	accessibility	investment in local / global community (charities)	integration of cultural heritage	transparency of company procedures	regenerative CSR programs		x
Covered	3	3	3	0	3	0		
Education	participatory processes	inspiration / education						xx
Covered	2	3						
Economics	participation in sharing economy	restorative enterprise	building circular economic value chain					o
Covered	1	0	1					
Place	regenerative land use	local community agriculture	biodiversity	community connectivity	bioclimatic design	regenerative heritage	topophilia	xxx
Covered	3	3	3	3	3	3	3	
Energy	non polluting energy sources	onsite renewable supply	net positive energy	onsite storage for resiliency				xxx
Covered	3	3	3	3				
Water	net zero water use	local stormwater management	wastewater treatment onsite without chemicals					xxx
Covered	3	3	3					
Wellbeing	working conditions connected to nature	IAQ	biophilic design	water quality	healthy food accessibility	design for active lifestyle	visual comfort	x
Covered	3	3	3	0	0	0	0	
	thermal comfort	acoustic comfort	mental health	medical support				x
	2	0	0	0				
Carbon	net zero lifecycle CO2 emissions	carbon negative technologies						xxx

0 – Not substituted; 1 – Indirectly covered; 2 – Covered; 3 – Covered, same goals. LEED does not cover the equity and education topics at all, nor does it set ambitious goals in the other categories.

- دراسة نظرية حول تطبيق الطاقة الصافية الإيجابية على المباني المكتبية والإطار الذي يعمل فيه نظام الطاقة الصافية الإيجابية. (الفصل الثاني).

❖ **المرحلة التحليلية**

- تحديد استراتيجية التصميم المتجدد من العديد من مشاريع تصميم الهندسة المعمارية الأكاديمية التي طبقت مبادئ النظام لتحقيق أهداف صافي الطاقة الإيجابية. (الفصل الثالث).

❖ **المرحلة العملية**

- استخدام برنامج المحاكاة eQUEST وPVsyst لبناء وتحليل أداء الطاقة لمبنى إداري في القاهرة (الفصل الرابع).

هيكل البحث

يتكون البحث من اربعه فصول على النحو التالي :

الفصل الاول

يناقش هذا الفصل منهج التصميم التجديدي للوصول إلى بيئة بناء متجددة للمساهمة في مواجهة التغير المناخي. وتم مناقشة الفصل علي النحو التالي: أولا، تقديم لمحة عامة عن التصميم التجديدي. بعد ذلك، استعراض المبادئ والتعاريف الرئيسية للتصميم التجديدي وإمكاناته وأهميته. وأخيرا، يناقش أدوات دعم النهج التجديدي التي تعمل على تبسيط الأسس النظرية لعملية التصميم التجديدي.

الفصل الثاني

يستعرض الفصل الثاني أحد تطبيقات التصميم التجديدي في مجال الطاقة. ويعرض مفهوم صافي الطاقة الإيجابية، والفروق بين الطاقة الصفرية وصافي الطاقة الإيجابية، وكيفية عمل النظام في المباني.

الفصل الثالث

أما الفصل الثالث فسوف يتم تحليل معايير التصميم لمباني مكتبية من خلال الأثر البيئي واستهلاك الطاقة.وذلك التي طبقت معايير التصميم التجديدي وحازت علي شهادة تحدي البناء الحي وذلك لتكون مرجعا لتصميم الابنية المكتبية المصرية.

الفصل الرابع

يقدم الفصل الرابع النتائج، والتي هي في شكل مبادئ توجيهية للتصميم، لوصول المباني المكتبة الي صافي الطاقة الايجابية والذي يعتبر احد تطبيقات التصميم التجديدي التي تمت مناقشتها في الفصول السابقة؛ وهذا يؤدي إلى فكر جديد يمكن أن يكون مصدرا للتطوير والمناقشة في مجال مفهوم التصميم المعماري في مصر. ويتضمن هذا الفصل أيضًا دراسة محاكاة حاسوبية تم تطبيقها على مبني مكتبي في القاهرة، مصر ، حيث استخدمت النتائج في تصميم المبادئ التوجيهية للتصميم التجديدي والوصول الي صافي الطاقة الإيجابية.

المشكلة البحثية

القضايا البيئية التي تواجه العالم اليوم هي تغير المناخ وتأثيره على حياة الإنسان. النمو السكاني هو أحد أسباب زيادة استخدام الطاقة. ونتيجة لهذا الاستخدام هو تراكم كبير من انبعاثات ثاني أكسيد الكربون، مما تسبب في ظاهرة الاحتباس الحراري. وتشكل هذه التحديات قلقاً شديداً على مستقبل مصر. يعد قطاع البناء والتشييد أكبر القطاعات المستفيدة من الموارد الطبيعية فيما يتعلق باستخدام الأراضي واستهلاك المواد الخام. تعد إزالة الكربون من قطاع البناء بحلول عام 2050 أمرًا ضروريًا لتحقيق أهداف خفض الانبعاثات هذه وحل تحدي تغير المناخ الأكثر أهمية. وفي عام 2022، شكلت انبعاثات قطاع البناء نحو ثلث إجمالي انبعاثات نظام الطاقة، بما في ذلك عمليات البناء (26%)، وكذلك الانبعاثات المتجسدة (7%) من تصنيع المواد المستخدمة في بنائها. إن استراتيجيات التخفيف والتكيف مطلوبة طوال دورة المبنى بأكمله وذلك حيث أن الطاقة هي أكبر مصدر لانبعاثات ثاني أكسيد الكربون العالمية في البيئة المبنية. ونما استهلاك مصر من الطاقة بنسبة 52% بين عامي 2005 و2021. وتقدر الدراسات العلمية أنه بحلول عام 2060، وبسبب تغير المناخ، من المتوقع أن يرتفع متوسط درجة الحرارة في القاهرة بمقدار 4 ◦ مئوية، وفي باقي أنحاء مصر من 3.1 إلى 4.7 ◦ مئوية. ونتيجة للحرارة العالية، فإن تعرض عدد السكان ذوي الدخل المنخفض إلى الظروف المناخية الخطرة قد يرتفع.

الدافع البحثي

يركز التصميم المتجدد بشكل أكبر على البيئة الطبيعية، التي تتجاوز مستويات التصميم الأخضر والمستدام لأنها لا تميل فقط إلى إنتاج إمدادات الحياة اليومية مثل الطاقة والمياه ولكنها مصممة لتطوير الأنظمة البشرية مع الأنظمة الطبيعية لتوليد منافع متبادلة و تعبير عام أكبر عن الحياة والمرونة.وبما أن مصر تسعى إلى الحفاظ على البيئة من خلال الاستخدام الرشيد للموارد، فإن إطار رؤية مصر 2050 يهدف إلى تحقيق ذلك من خلال معالجة تأثير تغير المناخ وزيادة استخدام الطاقة المتجددة. سوف تستكشف هذه الأطروحة كيف يعزز النهج التجديدي خطة مستقبل مصر من خلال زيادة كفاءة استخدام الطاقة.

الهدف من البحث

وضع مبادئ توجيهية للتصميم للتصميم التجديدي من خلال تطبيقها على مباني المكاتب في القاهرة لتحقيق صافي الطاقة الإيجابية.

منهجية البحث

تعتبر الدراسة بحثًا تطبيقيًا يحتاج إلى منهج متكامل. ويتم تحديث هذا المنهج لدراسة المعايير التجديدية على أساس الارتباط بين الإطار العلمي (الاتجاه النظري) والممارسة (الاتجاه التطبيقي)، ويتيح أقصى قدر من التفاعل بين الاتجاهين. يتم استخدام ثلاث مراحل للوصول إلى النتائج النهائية للأطروحة، كما هو مذكور أدناه:

❖ **المرحلة النظرية**

- دراسة نظرية عن التصميم التجديدي للمباني من حيث المفهوم والمبادئ والاستراتيجيات (الفصل الأول).

الملخص

أدت عواقب السلوكيات البشرية غير المستدامة إلى تدهور بيئي عالمي لا مثيل له، وتحتاج معالجة آثار التغير المناخي إلى استجابة عاجلة وجماعية بشكل خاص. وتعتبر المناهج التقليدية للاستدامة التي تسعى إلى التخفيف من الضرر أو تحييده غير كافية لمعالجة العواقب البيئية والاجتماعية المتراكمة للنشاط البشري. بينما تعتبر صناعة البناء والتشييد من أكبر المساهمين في العديد من القضايا التي يواجهها العالم، خاصة في بلد يمر بالتنمية الحضرية والتصنيع السريع مثل مصر. وقد اعتبرت البيئة العمرانية الآن أكبر مستهلك لموارد الطاقة والموارد الطبيعية في العالم. ولذا فإن اتباع نظام يهدف إلى التأثير الإيجابي على البيئة أمر ضرورى من خلال نهج متجدد لتوفير أطر عمل بديلة. يدور التصميم التجديدي حول فهم قدرة المبنى وتأثيره على الأشخاص والمجتمعات والأنظمة الطبيعية الأخرى. ويعتبرأحد المتطلبات الأساسية المهمة للنهج التجديدي هو أن يتجدد باستمرار التفكير والاتصال بالصحة كنظام حي واحد. كان الهدف الرئيسي للبحث هو وضع مبادئ توجيهية للتصميم التجديدي من خلال دراسة مفهومه واستراتيجيات التنفيذ والمبادئ الأساسية التي يجب مراعاتها في عملية التصميم. . لتبسيط عملية التصميم التجديدي ، استخدمت أداة دعم تحدي البناء الحي ، والتي ناقشت مباني الطاقة الإيجابية الصافية ، حيث لا تهدف المباني إلى توليد الطاقة فحسب ، بل تحديد الغرض وطريقة التعامل مع الموارد لتوفير أكثر مما يتطلبه المبنى.

تتكون منهجية البحث من دراسة نظرية لكل من التصميم التجديدي، وصافي الطاقة الإيجابية، ومن ثم استخدام النهج التحليلي، من خلال دراسة مباني إدارية معتمدة كمثال يتضمن مبادئ التصميم التجديدي. لتقييم كفاءة الحلول التجديدية تم تطبيقها على مبنى إداري في القاهرة واختبارها من خلال برنامج محاكاة وذلك للوصول إلى مباني الطاقة الصافية الأيجابية. توصل البحث إلى التأكيد على أن النهج التجديدي يوفر تصميمًا فريدًا للتفاعل مع عالم حي من خلال تركيزه على شراكة إبداعية مشتركة مع الطبيعة بناءً على استراتيجيات التكيف والمرونة والتجديد. كما توفر المباني المتجددة فرصة لتقديم العديد من الخدمات ذات الأثر الإيجابي على البيئة. وأن تأخذ التصميمات في الاعتبار دائمًا الترابط بين الأنشطة البشرية والطبيعة التي لها تأثير مباشر على استهلاك الطاقة والبيئة والاستدامة.

الكلمات المفتاحية: التغيير المناخي ، التصميم التجديدي ، أداة تحدي البناء الحي ، صافي الطاقة الإيجابية ، مباني المكاتب.

بيانات الباحث

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تاريخ الميلاد: 14 ديسمبر 1995

مكان الميلاد : مصر

آخر درجة علمية: بكالوريوس العلوم

مجال التخصص: الهندسة المعمارية

الجامعة التي أصدرت الشهادة : جامعة سيناء

تاريخ الحصول على الدرجة: 2018

الوظيفة الحالية: مهندس معماري

جامعة عين شمس
كلية الهندسة
قسم الهندسة المعمارية

اسم الباحث: سلوي أنيس عزالعرب

عنوان الرسالة: التصميم التجديدي للمباني الإدارية في القاهرة لاستخدام الطاقة الإيجابية الصافية.

اسم الدرجة: ماجستير العلوم في الهندسة المعمارية.

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تاريخ البحث: ..../........../........

الدراسات العليا:

ختم الاجازة:
اجيزت الرسالة بتاريخ :......../............./.........
موافقة مجلس الكلية:............./............/.........
موافقة مجلس الجامعة:.........../............/.........

جامعة عين شمس
كلية الهندسة
قسم الهندسة المعمارية

اسم الباحث: سلوي أنيس عزالعرب

عنوان الرسالة: التصميم التجديدي للمباني الإدارية في القاهرة لاستخدام الطاقة الإيجابية الصافية.

اسم الدرجة: ماجستير العلوم في الهندسة المعمارية.

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تاريخ البحث: ..../........../........

الدراسات العليا:
ختم الاجازة:
اجيزت الرسالة بتاريخ :......../............/........…
موافقة مجلس الكلية:............./............/.........
موافقة مجلس الجامعة:.........../............/.........

جامعة عين شمس
كلية الهندسة
قسم الهندسة المعمارية

التصميم التجديدي للمباني الإدارية في القاهرة لاستخدام الطاقة الإيجابية الصافية

رسالة مقدمة للحصول على درجة ماجستير العلوم في الهندسة المعمارية

اعداد

م. سلوي أنيس عزالعرب

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