SUSTAINABLE INFRASTRUCTURE DESIGN USING BIM

By

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Islamabad, Pakistan
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Supervisor: **Dr. Safi Ur Rehman**
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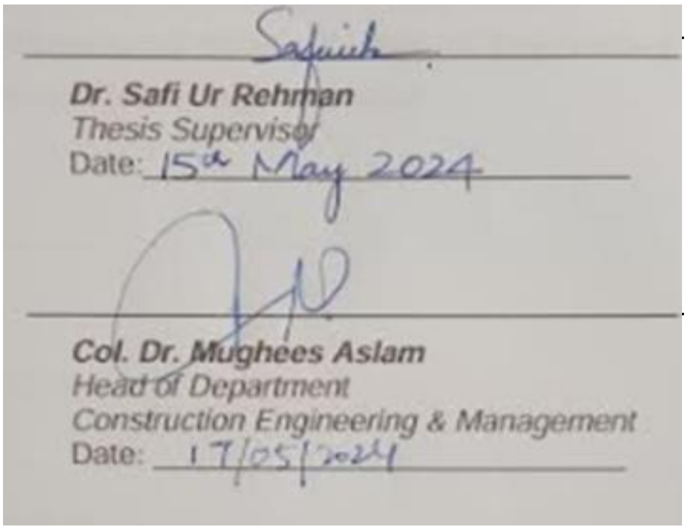

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CERTIFICATE OF APPROVAL

This is to certify that the research work presented in this thesis, entitled "***Sustainable Infrastructure Design Using BIM"*** was conducted by ***Uzair, Hamid, Saad*** and ***Mujtaba*** under the supervision of ***Dr. Safi Ur Rehman.***

No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the ***Department of Construction Engineering & Management*** in partial fulfillment of the requirements for the degree of ***Bachelor of Engineering*** in the Field of **Civil Engineering** at *Department of Construction Engineering & Management*, **Military Collage of Engineering**, National University of Sciences and Technology, Islamabad.

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We ***Uzair, Hamid, Saad*** and ***Mujtaba*** hereby state that my BS thesis titled ***“Sustainable Infrastructure Design Using BIM”*** is our own work and has not been submitted previously by us for taking any degree from National University of Sciences and Technology, Islamabad or anywhere else in the country/ world.

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DEDICATION

Dedicated to the visionaries, innovators, and stewards of our planet's future. To those who believe in the power of sustainable buildings and infrastructure to shape a better world for generations to come. This thesis is dedicated to the tireless efforts of individuals, communities, and organizations committed to fostering environmental harmony, social equity, and economic resilience through thoughtful design and responsible stewardship. May our collective endeavors pave the way for a more sustainable, inclusive, and thriving world.

ACKNOWLEDGEMENTS

We would like to express my deepest gratitude to Dr. Safi Ur Rehman for his unwavering support, guidance, and expertise throughout this project. His encouragement and insights have been invaluable in shaping the direction of this research.

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We extend my appreciation to my family and friends for their understanding, encouragement, and patience during this journey. Their unwavering support has been a source of strength and motivation.

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Lastly, we acknowledge the countless individuals, communities, and organizations dedicated to sustainability and environmental stewardship, whose work inspires and informs my own. Together, we can create a more resilient, equitable, and sustainable future for all.

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ABSTRACT

The global ACEF industry is swiftly embracing the digital revolution through various BIM platforms. These platforms provide efficient eco-friendly methods to increase quality across sectors. Despite global advancements, regions like Pakistan face limitations such as shortage of resources and budget. Hence, the goal of this project is to design an efficient green energy structure for the Cadets Battalion in Risalpur Cantt, employing BIM technology as a tool. The focus is on enlightening people about green building concepts to reduce costs, improving user friendliness, and environment preservation.

This Final Year Design Project encompasses data accession, architecture, modeling, design, analysis, and presentation for modernizing the Cadets Battalion in Risalpur Cantt. Using cutting edge technology materials, the project aims to create an energy-efficient green structure within green building standards, advantageous for technical cadets and Military College of Engineering. It focuses on using BIM platform for green building design to raise recognition among professionals, aiming to make it cost effective, improve solace, and preservation of environment.

Keywords: Sustainability, Green Buildings, BIM, ACEF Industry.

CHAPTER 1 INTRODUCTION

In our rapidly urbanizing world facing environmental challenges, sustainable infrastructure design emerges as a critical solution. This project delves into the transformative potential of sustainable infrastructure, aiming to integrate principles of sustainability, innovation, and inclusivity into infrastructure development. By exploring interdisciplinary perspectives and real-world case studies, we seek to uncover pathways towards infrastructure that not only meets human needs but also fosters environmental regeneration, social equity, and economic resilience. Through collaboration and creativity, we aspire to inspire a future where infrastructure serves as a beacon of sustainability and hope for generations to come.

1.1 Background

BIM (Building Information Modeling) the most common working and collaboration platform along with the concept of Green Buildings, Net Zero Energy Buildings, Eco- friendly Developments effectively being used by Architectural / Engineering / Construction / Facility Management (AECF) Industry of modern developed regions of the world, enhancing Productivity, Quality, Quantity and Schematics of works in many ways also promoting the life time savings of Resources, Cash and Efforts towards the Project Execution and Maintenance. That formerly includes many aspects of efficient designs, productive work formations, and concepts of simple and complex sciences.

BIM is on the path become a superior identified orthodox collaboration platform in the field of construction. Owners / Stakeholders are to an increasing extent requiring BIM services from construction administrators, engineering, and architecture organizations. Investment in “BIM” tools by construction firms are increasing during bidding, construction, preconstruction, and post construction. One of the primary goals of this Final Year Design Project (FYDP) is to recognize the benefits of BIM as well as the process of BIM Implementation for construction managers, designers, and examine BIM based working environments.

Green Buildings, Net Zero Energy Buildings, and Eco-friendly Development are most common concepts in design and development now a day that incorporates the objectives like Minimizing Need of Resources and Power, Optimizing Effective Utilization of Resources, and in some ways Using Renewable Resources for the basic needs. Most of the undeveloped and developing areas are also facing major problems just caused by the already built non-green traditional structures that are a mess creating hurdle in the way of upgrading the system of AECF Industry. Thus, both upcoming new constructions and modification of existing ones demands Green & Performance Efficiency concepts.

Key objectives of this project are to design a sustainable infrastructure using current stages of BIM in the AECF industry to better identify just how the BIM-based "design to build" concepts can be used by AECF industry of Pakistan. After identifying the Green Building Standards and to utilize those standards in designing and analysis phases of a project for entirely new construction and retrofitting of existing ones. It is also aimed to emphasize the ways to enhance the performance efficiency of sustainable infrastructure.

The topic of this *case study-based research project* is "Sustainable Infrastructure Design Using BIM". BIM Platforms and Green Building concepts will be applied for new construction and optimizing the existing as well.

1.2 Green Building Concept

Processing the concepts of energy efficiency, eco-friendly development, environmental and landscape preservation, reduction of pollution, effective resource utilization all together at one stage is being the most common practices of the developed countries and the true master trick of their economic & productive growth. Green buildings, net zero energy buildings, and eco-friendly development are most common concepts in design and development now a day that integrates the objectives like minimizing need of resources and power, optimizing effective utilization of resources, and in some ways using renewable resources for the basic needs.

1.2.1 Rationale of Green Buildings

Buildings are weighty customers of resources and energy in a society. Energy preservation in structures plays a significant role in environmental sustainability in urban areas. A demanding task of architects and experts in this era is to design and hearten low energy buildings in an environmentally responsive and cost effective way. low energy passive architecture has been projected and investigated in different locations of the world (Shaviv 2008), handbooks and design guides were produced for endorsing energy efficient buildings (Kolokotroni, Ren et al. 2012).

1.2.2 Green Retrofitting Concept

For the sake of consistency, this research uses the description provided for a retrofit project, which is: “A retrofit development is the modification or alteration (not complete replacement) of an existing process, facility, or structure. Such alterations may involve additions, deletions, rearrangements, or not-in-kind replacements of one or more parts of the facility. Changes may vary the kind, quantity, cost or quality of products or services being synthesized by the facility”. Most of the undeveloped and developing areas are also facing the major problems just caused by the already built non-green conventional/traditional structures that is mess creating hurdle in the way of upgrading the system of AECF Industry like in Pakistan, the modes of construction have been used before are not actually considered the standards and benefits of being green development country. Here the solution to the stated problem lies in concept of retrofitting the existing in such a way that could optimally meets the standard requirements for going green and having efficient performance characteristics of the existing buildings there after the modifications.

1.3 BIM Implementation

The AECF-Industry has been straggling different types of fabrication businesses in terms of yield and improvement. The cause for this has been narrated as to be a blend of collective needs in executing projects combined with the split essence of the AECF- industry (Lindblad 2013). Also, on regional basis most of the developing countries are way behind the developed countries, even Pakistan is one of them. That is because of the many limiting constraints discussed in this Project. Building Information Modelling (BIM) has been offered as a way of dealing with these concerns and hence refining yield in construction assignments. This Research Project examines how BIM has been embraced in Sustainable Infrastructure Design. The research intents to refine the understanding of the processes of implementing BIM and its effectiveness in New and Existing Construction concepts to make it handier for the AECF-industry in technologically lagging regions like Pakistan.

The acceptance of BIM has been gradual, and many obstructions delaying extensive acquisition of this technology have been visible. Therefore, this Research project answers questions like What, How, When, Where, related to BIM Execution in the simplest way possible. There is however no sole wall that could be solved discretely to permit more wide scale BIM adoption. These walls are obstructing many different facets of effective adoption of BIM When related to old-style 2D CAD systems; whatsoever BIM is a more effective way of handling facts related to the construction venture or the building. Adoption of BIM allows changes in work procedures that can rationalize the performance in construction assignments.

1.4 Problem Statement

There is a lack of implementation of BIM and Sustainable Infrastructure Design in AECF industry. This may be because of below stated major issues:

a) Designers and planners having lack of related knowledge and concepts.
b) Stakeholders having little or no knowledge of benefits of the concepts, implementation to project for lifetime resource and monetarily savings.
c) Lack of knowledge of locally available resource utilization, for the purpose.
d) Lack of technically trained manpower, equipment, and supplies centres,
e) Locally implementing standards and policies.

1.4 Objectives

Key objectives of this thesis are as follows:

a) ***Design and Analysis of Conventional Buildings and Infrastructure***

It includes the Designing, Modelling and Analysis of conventional infrastructure on BIM Platforms. It emphasizes the process of BIM implementation along with the analysis showing the energy consumption of the infrastructure.

b) ***Design and Analysis of Sustainable Buildings and Infrastructure***

It includes the phases of proposing Green & Effective Design for new structures and Retrofitting ways for existing structures, and analysis on BIM Platform showing the difference and enhanced parameters after modifications.

c) ***Comparative analysis of Sustainable design with Conventional Design***

It compares sustainable design practices with conventional approaches in the AECF industry. Using BIM platforms, it quantifies the benefits of sustainable design.

1.5 Significance of Study

This research project, "Sustainable Infrastructure Design Using BIM," holds immense significance, particularly within the context of Pakistan and for the technical cadets of MCE. Undoubtedly, in this new era, the energy sector's pivotal role in our country's development is undeniable. The outcomes of this project are poised to provide enduring benefits to the future cadets of MCE, equipping them with a self-sustaining facility complete within itself. Aspects of Sustainable Infrastructure Design that can easily be utilized within Pakistan’s limiting constraints are:

a) Modern Architecture concepts for Green Buildings.
b) Effective Implementation of BIM Platforms in Designing and Planning Stages.
c) Initial single Time and Lifetime, Comparative analysis for Duration and Budget for Green Infrastructure and Conventional Infrastructure.
d) Incorporating Environmental preservation factors and Landscape preservation in Designing phases along with building aesthetical configuration.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Infrastructures play a decisive role in the socio-economic-development of state energy and resources, together with its use. Accordingly, the implementation of energy efficiency in buildings is a key target. Also, the use of BIM Platforms has enumerated many positive aspects in Development & AECF Industry. Therefore, this literature review gives an indication of multidisciplinary studies on the present state of the analysis of BIM Implementation process, usability, productivity for Energy Efficient & Green Infrastructures, Modification & Improvements in the building in construction sector. This study determines that it is easy and reliable to incorporate the efforts to implement BIM in AECF Industry and Green Building concepts in regions like Pakistan in its construction sectors at all levels (national and local) to grow Effective, Modern & Efficient governance in AECF Industry of Pakistan.

2.2 BIM

The simple theory behind Building information modelling is well defined by Thompson and Miner (2007), in that; if all important information linked to a project were stored in a single coordinated system, the project could be achieved in a digital environment first. When magnitudes of time (scheduling) and prices are added to the model, it assists cost-time benefit investigation of various options almost instantly (Hackney, Burke et al. 2007).

2.2.1 Level of Details (LOD) in BIM

A summary of BIM LoD is presented in Table 1 (Bedrick 2008; Leite and Akcamete 2010).

2.2.2 Dimensions of BIM

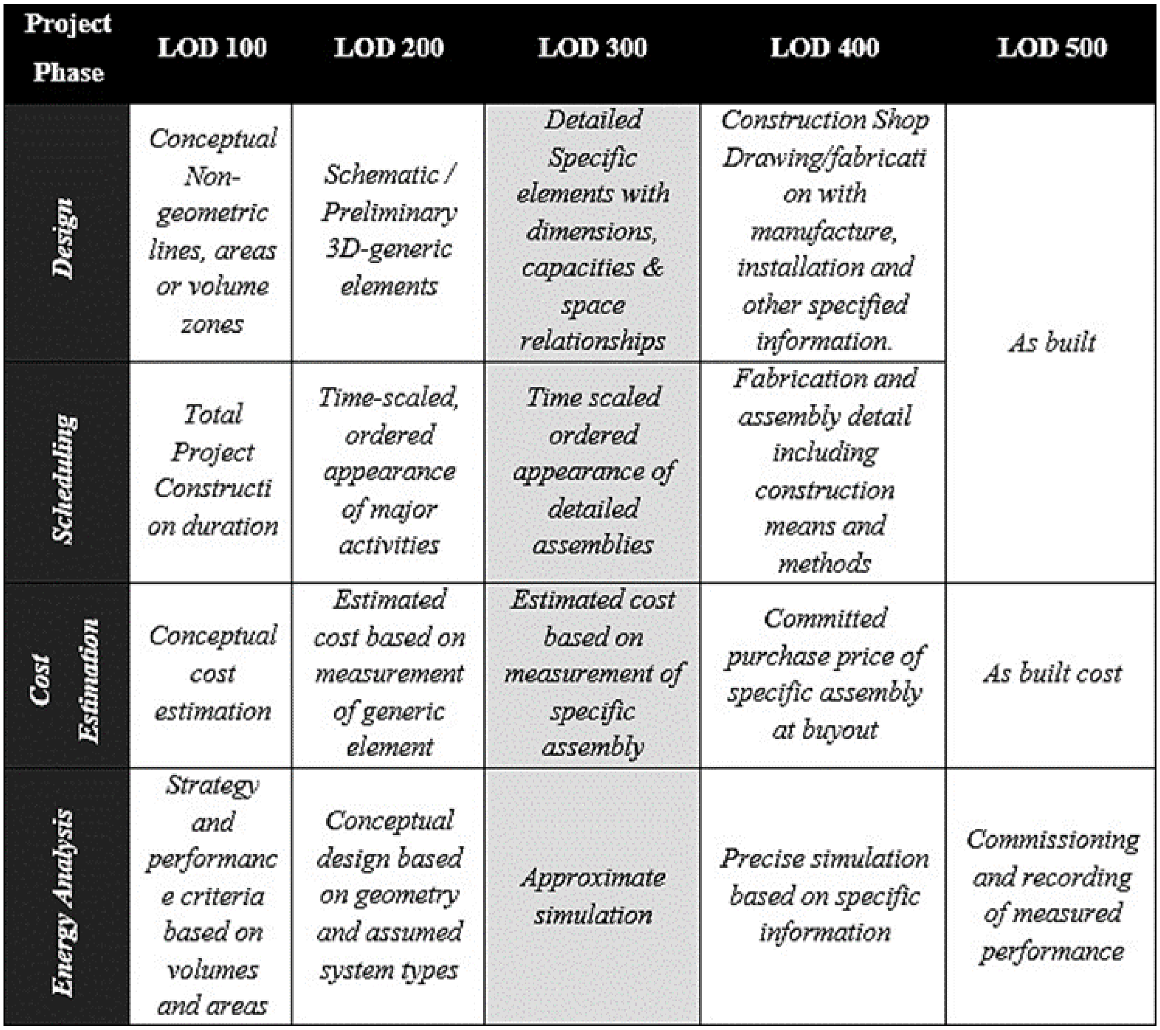
Building information modelling is a novel way of crafting, sharing, swapping, and handling the data in the project throughout the building’s complete lifespan. In this

BIM can be categorized into different parts covering (Bazjanac 2007; Isikdag, Aouad et al. 2007):

- Product – An intellectual picture of the building. It is considered as a source of data to be utilized by the owner or operators and preserved throughout the building's complete lifespan.
- Collaborative process – Covering business standards, computerized process abilities and synergism for sustainable information practice.

BIM includes multi-disciplinary levels and analysis platforms that are specialty based differentiated accordingly. The basic theory behind BIM is in all its Dimensions if described individually as presented in Table 2. A description of BIM dimensions is as follows:

Table 1 BIM Level of Details (LoD)



Project Phase	LOD 100	LOD 200	LOD 300	LOD 400	LOD 500
Design	*Conceptual Non-geometric lines, areas or volume zones*	*Schematic / Preliminary 3D-generic elements*	*Detailed Specific elements with dimensions, capacities & space relationships*	*Construction Shop Drawing/fabrication with manufacture, installation and other specified information.*	*As built*
Scheduling	*Total Project Construction duration*	*Time-scaled, ordered appearance of major activities*	*Time scaled ordered appearance of detailed assemblies*	*Fabrication and assembly detail including construction means and methods*	
Cost Estimation	*Conceptual cost estimation*	*Estimated cost based on measurement of generic element*	*Estimated cost based on measurement of specific assembly*	*Committed purchase price of specific assembly at buyout*	*As built cost*
Energy Analysis	*Strategy and performance criteria based on volumes and areas*	*Conceptual design based on geometry and assumed system types*	*Approximate simulation*	*Precise simulation based on specific information*	*Commissioning and recording of measured performance*

Table 2 BIM dimensions and their respective purposes

BIM Dimensions	Description / Purpose	Author
3D Coordination	*Visually interface checking with MEP integration reduce conflicts*	**(Azhar, Nadeem et al. 2008; Norbert, Stephen et al. 2009)**
Design and Constructability Reviews	*Analyze design for practicality and identification of errors and omissions*	**(Foster 2008)**
4D Scheduling and Sequencing	*Activities sequencing with visualization. Simulation for update time and resource schedule*	**(Wilson and Koehn 2000; Tulke and Hanff 2007)**
5D Cost Estimation	*Material quantities are extracted automatically and changed when any changes are entered in model. Micro and Macro Costing Models.*	**(Sabol 2008; Azhar 2011; Hergunsel 2011)**
6D Procurement	*Integration of subcontractor supplier and vendor data into isolated models.*	**(Foster 2008)**
Prefabrication	*Optimization of prefabricated construction components. Integration with MEP components*	**(Winberg and Dahlqvist 2010; Hergunsel 2011)**
Structural Analysis	*External analytical engine develops architecture design to structure and then analyzed for loading.*	**(Kaner, Sacks et al. 2008; Zhang and Hu 2011)**
Lightening Analysis	*Creation of effective, efficient, ambient and constructible lightening systems with enhancement in quality, cycle time and cost*	**(Masood, Kharal et al. 2014)**
Mechanical (HVAC) Analysis	*Clash, conflict and overlapping detection with computerized visualization.*	**(Foster 2008)**
Energy Analysis	*Energy analysis, delighting, orientation analysis, solar analysis, building, massing analysis and site analysis with Virtual Environment (VE).*	**(Azhar, Brown et al. 2009)**
7D Operation and Maintenance	*Facility management for renovation, repair, restoration, space planning, & operation maintenance. Security management & safety information such as emergency lighting, power, egress, fire extinguishers, fire alarm, smoke detector & sprinkler systems. RFID for gathering information from real world components in to BIM.*	**(Azhar, Nadeem et al. 2008; Liu 2010; Meadati, Irizarry et al. 2010)**
GIS based Visualization	*The model satisfies an enhanced visualized system by incorporating of as built site photographs*	**(Elbeltagi and Dawood 2011)**
8D Modeling with PTD	*Risk assessment of design component of facility for prevention through design.*	**(Kamardeen 2010)**

BIM 3D, Design Intents in a Collaborative Model

a) Upgraded imagining of the project, communication of design intent.
b) Improved multifaceted teamwork.
c) Compact overhaul.

BIM 4D, Schedules of Project and Time-based Variation Orders

a) Incorporating BIM with 4D CAD simulation models brings interest to contributors in terms of design and optimization.
b) Builders and constructors can enhance their building events and team collaboration.

BIM 5D, Budget of Project and Cost based Variation Orders integrating BIM with 5D CAD simulation models enables the formation of more well-organized, efficient, and maintainable constructions.

BIM 6D, Optimizing the Energy Consumption and Sustainability integrating BIM with 6D CAD simulation models leads to an overall reduction in energy depletion.

BIM 7D, Management of Asset, Life Cycles & Facility Management integrating BIM with 7D CAD simulation models elevates asset supervision from demolition to design.

We may have all disciplines complicated with a project sharing a sole database:

a) Structure, Architecture, Infrastructure, Mechanical, and Construction now can be synchronized in a way Intelligently Interlinked.
b) Designs & Models can now be guided directly to fabrication units.
c) Energy analyses at the inception of design, initial phases.
d) Construction budgets are becoming more foreseeable.

2.2.3 BIM Integrated Software’s

There are a lot of tools and computer software’s in the market available and for specified tasks each is efficient to perform individually; good combination makes it the best to produce the best possible output needed in coordinated way. Table 3 shows the tools that have been used to achieve the objective we have stated earlier in the 1st chapter.

Table 3 List of BIM Integrated Software

Company	Product/Tool	Purpose
Primary Design and formation		
Autodesk	*REVIT*	Architecture, Structure, MEP, Fixtures & Fabrications / 3D Digital Complex Conceptual Modeling with related Drafts.
	InfraWorks	Modelling and Analyzing Infrastructure Design Concepts with the Context of Built and Natural Environment
Analysis Tools		
Autodesk	*Eco. TECT Analysis*	6D Sustainability, Detailed Energy Analysis LEEDSustainable Elements tracking (Weather, Energy, Water, Carbon emission).
	Insight	6D/7D Building Performance Analysis (Life Management), Sustainability to some extent. (InCloud Web Based)
Animation Rendering for Stakeholders/Public Collaboration		
Autodesk	*Revit 3D LIVE*	Photorealistic image courtesy for models imported from REVIT.
Twinmotion	*Twinmotion*	3D/4D Rendering and Walkthrough formation.

2.3 Sustainable Infrastructure

The projects are designed, constructed, planned, decommissioned, and operated in a way to secure economic, financial, environmental (including climate resilience), social and institutional sustainability over the entire life cycle of the project is known as feasible infrastructure.

Efforts to device so-called “green” design practices have contained largely approval or eclectic adaptation of numerous tools and resolutions to perceived environmental complications. Many GBS-Green Building Standards have been issued by now that essentially rank a building by its physiognomies falling in line of Performance classifications and define them as Green or Not, Common of record standards is LEED.

Though new technologies are continually being advanced to supplement current practices in creating greener infrastructures, the common objective of sustainable infrastructure is to decrease the overall effect of the built environment on human health and the nature environment, Mostly Sustainable Infrastructure is characterized by:

a. Efficient use of Energy, Water and Resources.
b. Defending inhabitants Health and improving employee Productivity.
c. Decreasing Waste Contamination and Environmental Deprivation.

In any design, trade-offs are made among alternative solutions aimed to optimize building performance for various considerations arise as per GBS Systems.

a. Power & Energy Efficiency.
b. Environmental preservation & CO_2& Pollution control.
c. Architecture & Aesthetics.
d. Human Comfort & Ventilation/Temperature control.
e. Structural Performance.
f. Economy & effects on Budget.

2.3.1 Power & Energy Efficiency, Building Performance

According to the International Energy Agency IEA, structures will consume 41% of comprehensive global energy investments potential by 2035**,** (ESMAP.) but still Pakistan stand way behind. Power Efficiency can be accumulated through the following ways (Sisson and Van Aerschot 2007):

- *Designing and Construction of new buildings.*

Elegant and Well-executed new structures indicate the finest opportunity for reduction of cooling, heating, ventilating, and lighting loads. The most effective way to confirm that energy efficiency is considered hooked on the construction and design procedure is by announcing and imposing Building Energy Efficiency Codes.

- *Retrofitting the existing structures.*

Retrofitting surviving structures and substituting energy intense equipment are helpful for refining efficiency in energy in municipalities where building stock revenue is less. Cities need to be self -serving to seize this potential by requiring energy efficiency promotions as part of all momentous maintenance and equipment-substituting acts. For this to occur, permitting environment and effective project sponsoring and transfer procedure must be in place.

- *Establishment & Maintenance of energy management systems.*

Maintenance and establishment of effective energy supervision systems for observing and presiding over energy use in huge commercial and public buildings is a cost-effective means through which to improve energy productivity and condense energy mandate.

2.3.1.1 Urgent Challenge of Energy Efficiency

Structures are accountable for at smallest 40% of energy usage in most republics. The total figure is growing quickly, as structure booms. It is vital to act swiftly, because structures can make a chief influence to confronting climate variation and use of energy. Social, financial, and organizational obstacles obstruct the way of instant act, and three methodologies can help overwhelmed them: **(Sisson and Van Aerschot 2007)**

a. **Encourage interdependence** by adopting all-inclusive, combined methodologies between the investors that prove a mutual accountability responsibility concerning enhanced energy performance in structures and their communities.
b. **Make energy more valued** by those included in the operation, development, and use of buildings.
c. **Transform behavior** by instructing and inspiring the specialists included in building dealings to adjust their progression to value-added energy efficiency in buildings.

There are three main approaches to energy neutrality (Sisson & Van Aerschot 2007):

a. reduce buildings demand for energy by, for example, using energy efficient equipment.
b. Use locally manufactured energy from renewable and otherwise useless resources of energy.
c. Energy sharing– creates structures that generate excess energy and input it into an intelligent grid infrastructure.

2.3.1.2 Barriers and Challenges in Energy Efficient Developments

There are numeral obstacles and encounters inherent in enlightening EE in structures. And while numerous of these can seem intimidating at first, experience from different cities countries demonstrates several ways they can be surmounted. Other hurdles are sector-wide, such as energy grants or/ and an extensive lack of data and information on EE costs, benefits, and opportunities.

2.3.2 Architecture, Aesthetics and Building Design

"Sustainable architecture" is architecture which looks to cut down the negative environmental impact of structures by moderation and efficiency in the utilization of energy, development space, materials, and the ecosystem in the bigger picture. Common modern architectural reforms are:

- The American Institute of Architects (www.aia.org):

EPA and AIA share common goals for reducing carbon emissions from the nation's building inventory.

- Architecture 2030 (www.architecture2030.org):

Architecture 2030 encourages new buildings and renovations to be designed to use 50 percent less fossil fuel energy than the national average.

Building envelope establishes the limit between the exterior and interior situations and its precise selection is one of the most productive ways to a minimum the energy depletion associated with interior thermal ease. The building envelope is considered as a hurdle that defends from exterior condition. (Rodriguez-Ubinas, Montero et al. 2014).

CHAPTER 3 METHODOLOGY

Three key objectives stated in chapter 1 will be achieved through a case study-based research methodology. This chapter covers the procedure of research to be followed and is stated explicitly that how those objectives are going to be achieved. An overview of the research methodology is presented in Figure 1.

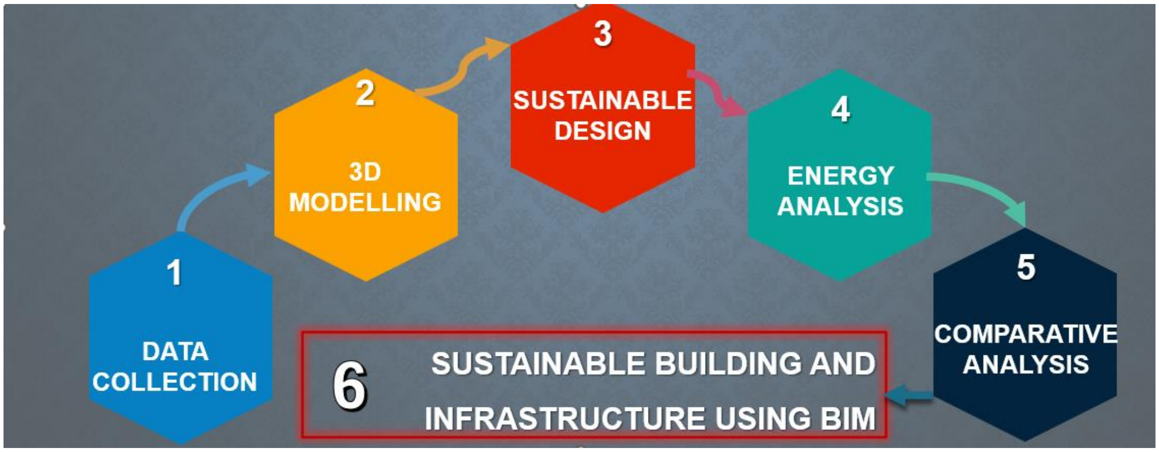


Figure 1 Research Methodology

3.1 Objective 1

Design and Analysis of conventional Buildings and Infrastructure

It includes the Designing, Modeling and Analysis of already existing infrastructure (Cadets Battalion).

3.1.1 Methodology to achieve objective 1:

1. In depth study of Cadet Bn plans and drawings.
    a. Acquisition of plans and drawings of already built buildings from relevant authority.
2. Conversion of Plans into model on BIM platforms.
    a. Make 3D Revit model form 2D plans for individual buildings.
    b. Make site plan for complete Cadets Battalion on Infraworks.
3. Analysis of Energy, water usage and solid waste of Cadets Battalion using BIM simulations.
    a. Carrying out BIM based Analysis.

    b. Carrying out Energy Analysis and Performance analysis according to GBS considerations.
4. Identification of weak points and improvable areas on simulated energy model.

3.2 Objective 2

Design and Analysis of Sustainable Buildings and Infrastructure

It includes the Designing and Modeling of an ideal infrastructure as per Green Building Standards on BIM Platforms. It emphasizes the process of BIM implementation along with the analysis showing the advantages of going Green and Eco-friendly.

3.2.2 Methodology to achieve objective 2:

1. In depth study of literature for Enhancing Energy Efficiency of a Green Building.
    a. Literature review and taking out applicable Retrofits within limiting constraints of Pakistan.
    b. A layout of how to apply those modifications.
2. Finding alternative ways to enhance efficiency & effectiveness.
    a. Proposing new innovative ways that are locally possible and acceptable.
    b. Applying those ways to models.
    c. Finding individual effectiveness of those proposals.
3. Updating Model and Loading them with relative information.
    a. Updating model for retrofits.
    b. Updating model with Energy tech. according to GBS.
4. Energy Efficiency Analysis of Retrofitted Infrastructure and comparison with Conventional one and analyzing if it falls in GBS considerations.
    a. Carrying out BIM based Analysis for retrofitting.
    b. Carrying out Energy Analysis and Performance analysis after Retrofitting.

3.3 Objective 3

Comparative analysis of Sustainable design with Conventional Design

It includes comparing the results of the energy analysis of conventional design with the results if sustainable one.

3.3.1 Methodology to achieve objective 3:

1. Obtain results of energy consumption of conventional design from BIM
2. Obtain results of energy consumption of sustainable design from BIM
3. Calculate the percentage reduction in energy consumption after implementation of sustainable alternatives.

3.4 Software Used

Software used and their respective purposes are presented in Table 4 and Figure 2.

Table 4 Software used in FYDP and their purpose.

Software	Purpose
Autodesk REVIT (2024)	3D Model
Autodesk Infraworks	Modelling Infrastructure Design
Autodesk Ecotect Analysis (2010)	Energy/Environmental Analysis
Twinmotion (2024)	3D Animations for Stakeholders
Green Building Studio (BIM Cloud)	Energy/Environmental Analysis
Autodesk Insight (BIM Cloud)	Solar Capture / Daylight Analysis2.4

Figure 2 Software used in FYDP.

3.5 Case Study

We took the Cadets Battalion, a facility made for the training of technical cadets of Military College of Engineering, in Risalpur Cantt, as our case study.

Figure 4 Site Details (Satellite Image)

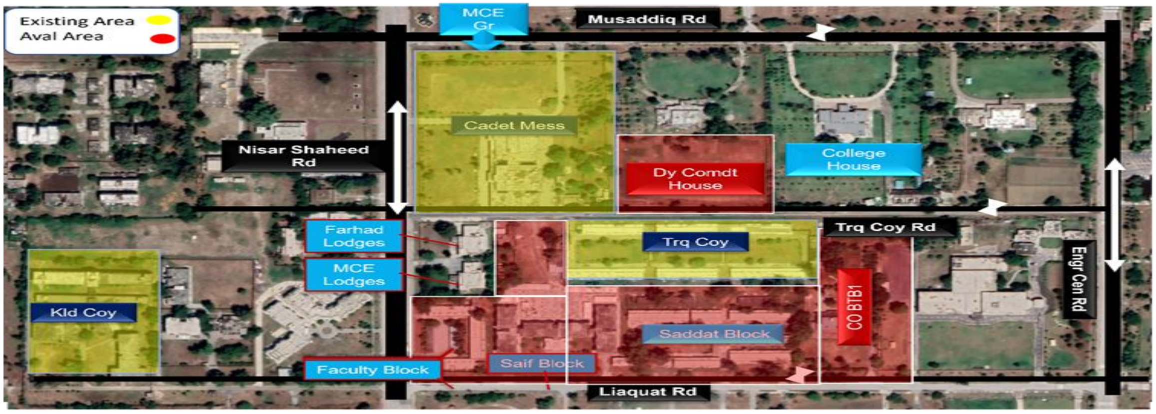


Figure 3 Project Details

CHAPTER 4 BIM BASED MODEL DEVELOPMENT

4.1 BIM Based Model Development (Conventional Design)

4.1.1 Architectural Model Development

Architectural Model development process was done using Autodesk REVIT 2024, for each level a cad file was linked to REVIT that helped to place components in 3D space of REVIT Architecture. When the model was developed it was made to be easily Linked energy analysis software. Architectural Models are shown below in figure 5 and 6.

4.1.2 Site Model Development

Unlike Architectural Model the Site Model was developed using Autodesk Infraworks. Using Autodesk Infraworks, we first made a model of our case study as shown below. When the model was developed, we imported the Revit models into Infraworks to develop the site model as shown below.

4.1.3 MEP Model Development

Using Architectural model, we first formed Plumbing model and applied Mechanical and Electrical fixtures in Revit 2024 as shown. After that each space was individually assigned to the type of use accordingly (like rooms and washrooms). When our Architectural and MEP Model was complete, we moved to form Energy Model assuming our design as conventional infrastructure.

4.1.4 Energy Model Development

We followed a simple procedure of mass model and building element strategy to predict basic energy analysis and model developed was shown below in figure 7, the results and analysis would be shown in further analysis chapters. Analysis and results will be shown in the upcoming chapters.

Figure 5 Saif Block Architectural Model

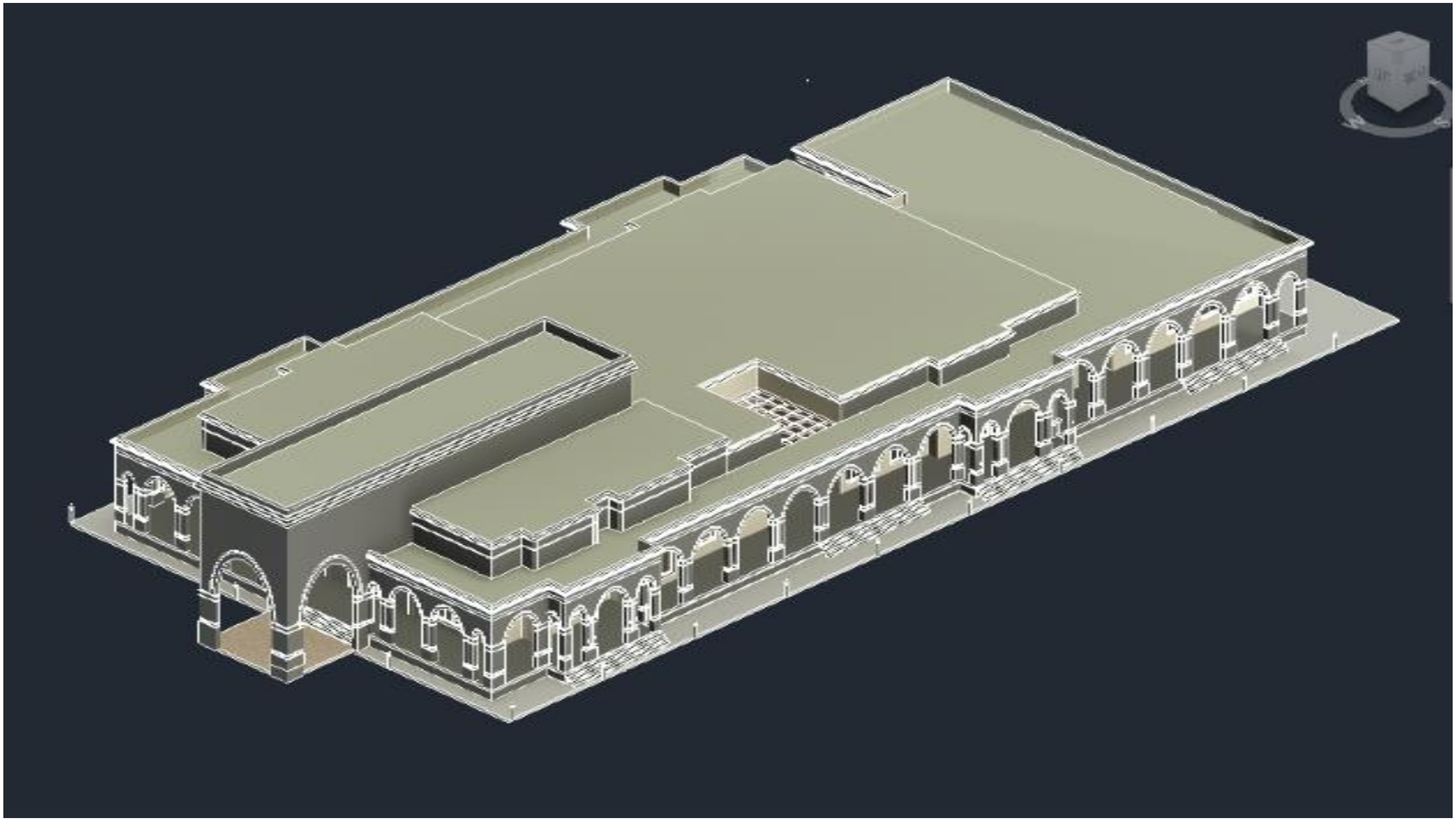


Figure 6 TC Mess Architectural Model

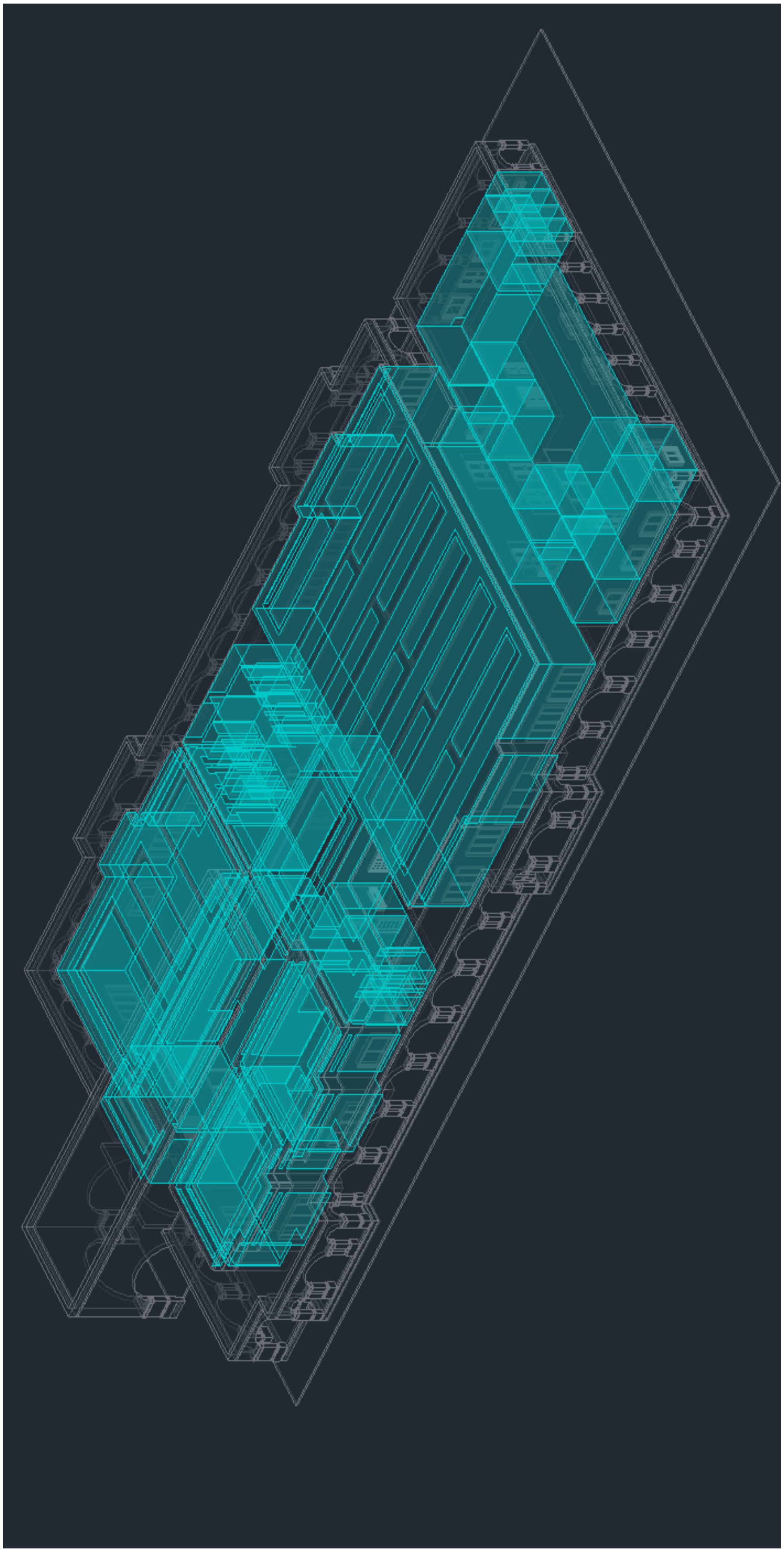


Figure 7 TC Mess Energy Model

4.2 BIM Based Model Development (Sustainable Design)

4.2.1 Sustainable Design Alternatives

We used the same model to be linked in REVIT 2024 and made changes to updates as to make conventional model Green and Energy Efficient, then followed a simple procedure of mass model and building element strategy to predict about new energy analysis outputs, model developed was shown below, the results and analysis would be shown in further analysis chapters. Then Whole model was updated using active and passive strategies for energy efficiency optimization. Active and passive energy conservation strategies are two distinct approaches to reducing energy consumption, each with its own set of characteristics and applications.

4.2.1.1 Active Energy Conservation Techniques

Active techniques involve the use of technology and systems that actively manage energy consumption. These systems often require energy to operate, such as motors, sensors, controllers, and electronic components.

The following active energy strategies were applied on our conventional design to reduce the energy consumption:

1. Convert most of Energy use to Solar System.
2. Change the Conventional Lighting System.

   Trail 1: ESL (Energy Saving Lights) →LED (Light Emitting Diodes)

   Trail 2: LED (Light Emitting Diodes) → SMD (Surface Mounted Diodes)
3. Proper System Monitoring and Occupancy Sensors to control Lighting Power uses.

Trial 1: Normal Lighting → Controlled Occupancy Sensor Lighting

4.2.1.2 Passive Energy Conservation Techniques

Passive techniques rely on design principles and natural processes to reduce energy consumption without the need for additional energy inputs. These techniques often focus on optimizing building design, orientation, and materials to enhance energy efficiency.

The following passive energy conservation strategies were applied on our conventional design to reduce the energy consumption:

1. Wall insulation done externally
2. Shading
3. Natural Ventilation
4. Roof Insulation
5. Glazing
6. Floor Insulation
7. White Cool Roof
8. Green Roof
9. Heat Pipes
10. Light Reflective Paint
11. Reducing Infiltration Rate

Both active and passive energy conservation techniques play important roles in reducing energy consumption and promoting sustainability. The most effective approach often involves a combination of techniques tailored to the specific needs and characteristics of the building or system in question.

Analysis and Results are presented in the next chapters.

CHAPTER 5 SOLID WASTE MANAGEMENT

5.1 Introduction

5.1.1 Solid Waste Management

Solid Waste Management (SWM) is a comprehensive and holistic approach designed to address the multifaceted challenges associated with solid waste. At its core, SWM aims to manage solid waste throughout its lifecycle, from generation to disposal, in a manner that is environmentally sustainable and socially responsible. This approach recognizes that solid waste management is not just about collecting and disposing of waste but also about implementing strategies that prioritize waste reduction, resource recovery, and pollution prevention. The key components of SWM include:

5.1.2 Waste Collection

Efficient and organized collection systems are essential for gathering solid waste from households, businesses, and institutions. SWM emphasizes the importance of optimized collection routes, proper waste segregation, and the use of suitable collection vehicles to minimize transportation costs and environmental impact.

5.1.3 Waste Transportation

Once collected, solid waste needs to be transported to processing facilities or disposal sites. SWM advocates for efficient transportation practices that reduce fuel consumption, emissions, and traffic congestion. This may involve using modern vehicles, route optimization technologies, and scheduling methods to streamline the transportation process.

5.1.4 Waste Processing

SWM promotes the use of environmentally friendly and sustainable ways for processing solid waste. This includes technologies such as anaerobic digestion, mechanical-biological treatment (MBT) and composting, to recover valuable resources from waste streams. These processes not only decrease the volume of waste sent to landfills but also generate renewable energy, compost, or recycled materials.

5.1.5 Recycling and Resource Recovery

A fundamental aspect of SWM is the promotion of recycling and resource recovery initiatives. This involves separating recyclable materials from the waste stream, such as paper, plastics, glass, and metals, and diverting them to recycling facilities. By recovering and reusing these materials, SWM reduces energy consumption, conserves natural resources, and minimizes greenhouse gas emissions.

5.1.6 Waste Disposal

For residual waste that cannot be recycled or recovered, SWM advocates for responsible and environmentally sound disposal methods. This may include modern landfilling practices that incorporate liners, leachate collection systems, and gas recovery systems to minimize environmental contamination. SWM also explores alternative disposal options, such as waste-to-energy facilities, to harness the energy potential of waste while reducing landfill reliance.

5.2 Waste Management Practices

Solid waste management is a critical aspect of environmental sustainability, ensuring that the waste generated by human activities is handled responsibly and efficiently. From the production of everyday items to the disposal of packaging and materials, effective management of solid waste is essential for safeguarding public health, preserving natural resources, and mitigating environmental pollution.

This explores the diverse array of techniques and methods employed in solid waste management, ranging from source reduction and recycling to advanced treatment technologies and responsible disposal practices. Each method plays a unique role in addressing the challenges posed by solid waste, offering opportunities to minimize waste generation, recover valuable resources, and minimize environmental impact.

By understanding and implementing these techniques, communities and organizations can work towards a more sustainable approach to managing solid waste, contributing to the well-being of both present and future generations.

5.2.1 Collection and Transportation

Efficient collection and transportation systems are pivotal in managing solid waste effectively, ensuring prompt removal from communities to processing facilities. Utilizing GPS tracking and route optimization technologies has notably enhanced collection efficiency. GPS tracking enables real-time monitoring of waste collection vehicles, facilitating agile route adjustments based on live data, such as traffic conditions or unexpected delays. Route optimization algorithms further refine collection routes, minimizing travel distances and time, reducing fuel consumption, and enhancing overall operational effectiveness. These advancements underscore a more streamlined and eco-friendly approach to solid waste management, emphasizing resource optimization and sustainability.

5.2.2 Landfilling

Landfills serve as engineered sites designed for the disposal of non-recyclable and residual waste. These facilities play a crucial role in waste management by providing a designated area for the safe and controlled disposal of materials that cannot be recycled or reused. Modern landfills are equipped with advanced features such as liners and leachate collection systems to mitigate environmental risks. Liners act as barriers between the waste and the surrounding soil, preventing potential leachate from contaminating groundwater sources. Leachate collection systems further enhance environmental protection by capturing and treating any liquid that seeps out of the landfill, reducing the risk of groundwater pollution. Additionally, modern landfills often incorporate systems to capture and utilize methane gas produced during waste decomposition, contributing to renewable energy generation, and minimizing greenhouse gas emissions. A typical landfill site is shown in figure 8.

5.2.3 Incineration (waste to energy)

Incineration is a waste management process which involves the combustion of waste materials at high temperatures, typically in specialized facilities known as incinerators. This method is employed to reduce the volume of waste and produce energy through the combustion process. Modern incineration technologies, particularly those used in waste-to-energy plants, have advanced significantly to not only reduce waste volume but also capture the heat produced during incineration for electricity generation. Waste-to-energy plants utilize this captured heat to produce steam, which then drives turbines to generate electricity, contributing to sustainable energy production. Furthermore, these advanced technologies incorporate emission control systems such as filters and scrubbers to cut down to a minimum the release of pollutants and ensure compliance with environmental regulations. As a result, incineration, when implemented with modern technologies, represents a viable approach to waste management that can simultaneously reduce waste volume, generate renewable energy, and minimize environmental impact.

5.2.4 Recycling

Recycling plays an important role in sustainable waste management by converting waste materials into new products, hence conserving resources, and reducing waste. Common recyclables include paper, plastics, glass, and metals as shown in figure 9, which undergo a series of steps including sorting, cleaning, and processing to prepare them for reuse. This process not only redirects waste from landfills but also conserves raw materials and reduces the energy and resources required for manufacturing new products. Recycling initiatives contribute significantly to environmental protection and resource conservation, making it an essential component of modern waste management practices.

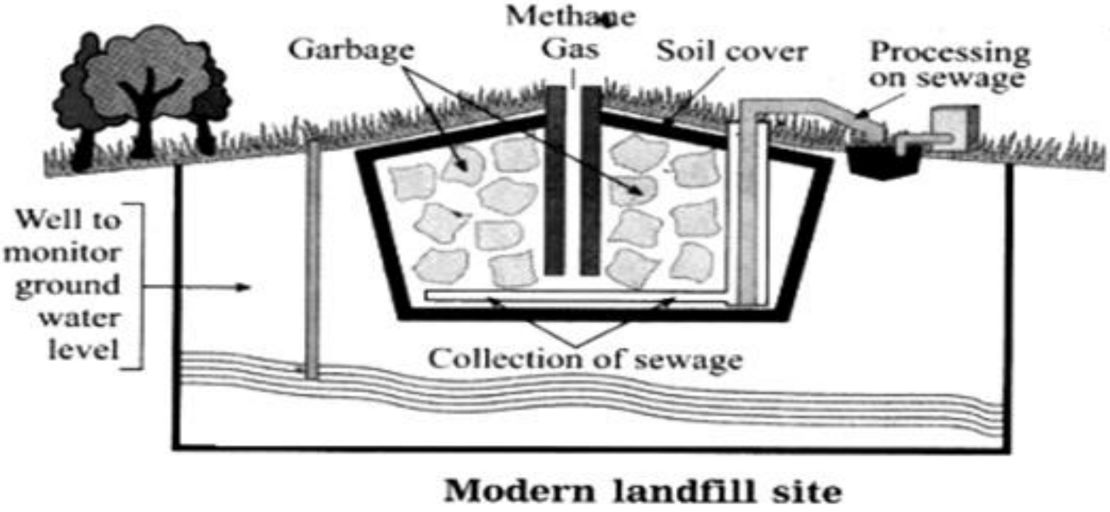


Figure 8 Landfill.

Figure 9 Waste Characterization.

5.2.5 Composting

Composting is a sustainable waste management practice that involves the conversion of organic waste, such as sewage, food scraps and yard trimmings, into nutrient-rich compost. This process promotes soil enrichment and supports sustainable agriculture by providing essential nutrients for plant growth. By diverting organic waste from landfills, composting helps decrease methane emissions, a potent greenhouse gas generated during the decomposition of organic materials in anaerobic conditions. Composting not only benefits the environment by mitigating greenhouse gas emissions but also contributes to soil health, water retention, and overall ecosystem sustainability. The composting cycle is shown in figure 11.

5.2.6 Anaerobic Digestion

Anaerobic digestion is a biological process which breaks down organic materials in the absence of oxygen, producing biogas (mostly methane) and nutrient-rich digestate. Anaerobic digesters can be used to treat organic waste from various sources, including food waste, agricultural residues, and wastewater sludge. Biogas produced during anaerobic digestion can be used as a renewable source of energy for electricity generation, heating, or transportation fuel, while the digestate can be used as a fertilizer or soil amendment. The process of biogas generation is shown in figure 10.

5.2.7 Segregation

Segregation in waste management is the systematic sorting of waste into different categories based on its type, composition, and recyclability. This process is crucial for efficient resource recovery and environmental sustainability. Source segregation, where individuals separate waste at the point of generation into bins for recyclables, organic waste, and non-recyclables, is a primary method. Material recovery facilities (MRFs) further refine segregation by using automated systems to separate recyclable materials like paper, plastic, glass, and metals from mixed waste streams. Proper segregation not only enhances recycling rates and reduces landfill waste but also minimizes environmental pollution and promotes a circular economy by facilitating the reuse and recycling of valuable materials.

5.3 Study Area

Analyzing solid waste management in Cadets Battalion, Risalpur Cantt, provides insights into potential of energy generation from solid waste.

In Cadets Battalion, waste is likely diverse, encompassing household, institutional, and industrial waste. The composition may lean towards non-biodegradable materials, reflecting the urban lifestyle. The waste generation rate is expected to be high due to population density and economic activities. The infrastructure for solid waste management is likely advanced, featuring organized collection systems, recycling facilities, and proper disposal methods.

Figure 11 Composting.

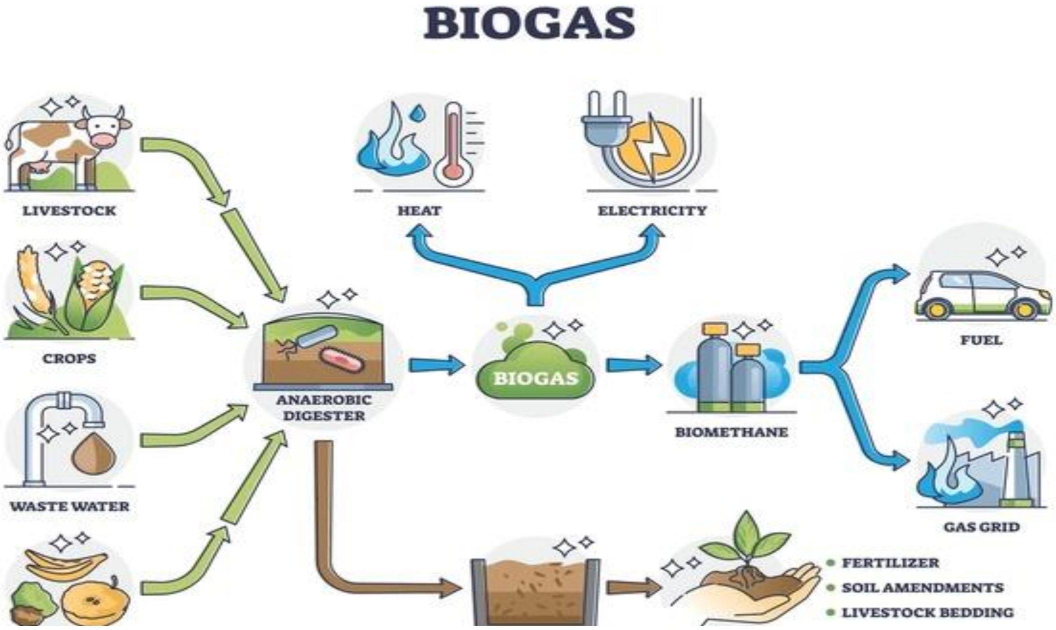


Figure 10 Biogas Production.

CHAPTER 6 WATER USAGE OPTIMIZATION

6.1 Introduction

Drinking water is an invaluable resource facing increasing pressure from climate change and the ever-increasing population. We need to enhance water consumption to guarantee water security in the foreseeable future and make these practices an invaluable part of sustainable infrastructure development. For this we must create systems that minimize waste and conserve it while providing clean water. This perspective combines technological advancements and responsible water management strategies. By keeping in view both the supply and demand we can build a safer water future. Here's a look into what water usage efficiency with sustainable infrastructure looks like:

6.1.1 Adaptive Technologies

- Detection systems for leakage, utilization of machinery in irrigation, farming and monitoring of water real time contribute to reducing waste to a minimum and increase efficiency.

6.1.2 Management of Demand

- Conducting public education campaigns and educating about water saving practices. Installation of smart faucets is essential to reduce consumption of water.

6.1.3 Green Infrastructure

Creating wetlands and natural filtration systems improves water quality and reduces pressure on traditional water supply. Enhancing water usage within a sustainable infrastructure framework is a win-win. It guarantees that communities have access to clean water while reducing environmental impact to a minimum.

6.2 Rainwater Harvesting

Rainwater harvesting is a practice that involves the collection, preserving and using of rainwater for different purposes. It has been in effect by people for thousands of years including the roman empire. In an age of increasing climate change uncertainties, rainwater proves to reduce dependency on conventional sources and supporting water supply, It also reduces the impact of water scarcity.

6.2.1 Importance of Rainwater harvesting

This antique technique has obtained renewed recognition in recent years due to its immense economic and environmental benefits. By capturing rainwater from windowsills, gardens, porch and catchment areas, rainwater harvesting systems provide a decentralized and efficient means of harnessing a valuable natural resource.

6.2.2 Versatile applications

From irrigation and landscaping to domestic use and groundwater recharge, rainwater harvesting presents versatile applications across residential, commercial, and agricultural sectors.

6.2.3 Promoting Sustainability and Resilience

As the population increases exponentially due to urbanization the stress on conventional water resources has become more noticeable. Rainwater harvesting provides an excellent alternative to alleviate stress. By including rainwater harvesting into water management strategies people can reduce unnecessary consumption of water and strain on existing water supplies. In conclusion, rainwater harvesting plays an important role in the aspect of promotion of water security, resilience, and sustainability in the face of growing water challenges.

6.2.4 Relevance to Sustainable Infrastructure Design

In the context of our Final Year Project (FYP) on sustainable infrastructure design using BIM, rainwater harvesting plays an important role and holds significant relevance along with potential integration. Harnessing of Rainwater harvesting emerges as a complementary sustainable solution in terms of developing energy efficient green structures within the limitations of green building standards.

1. **Water Conservation**: Rainwater harvesting systems provide us with an opportunity to conserve water resources by capturing and storing rainwater for different purposes, such as irrigation, drinking, dish washing and gardening. This is in line with our aim of promoting sustainability and minimizing the environmental effect of our projects.
2. **Integration with BIM Platforms**: With the use of Building Information Modeling (BIM) platforms we can integrate rainwater harvesting systems into our design process. The accurate modeling, analysis and optimized placement and sizing of rainwater harvesting components within our structures, ensuring optimal performance and efficiency with accuracy is possible.
3. **Resilience and Adaptation**: As the uncertainty of climate change and water availability is quite pronounced, including rainwater harvesting increases the flexibility of our structures. By diversifying our water sources and reducing dependance on central water supply systems, we can adapt to changing environmental conditions more efficiently.
4. **Local Context Considerations**: Considering the importance of rainwater harvesting in the local context, particularly in areas like Baluchistan of Pakistan facing water insufficiency, making it a part of the water management systems becomes even more essential. Our FYP provides an opportunity to scout revolutionary approaches to rainwater harvesting altered to the specific needs and limitations of our local communities.

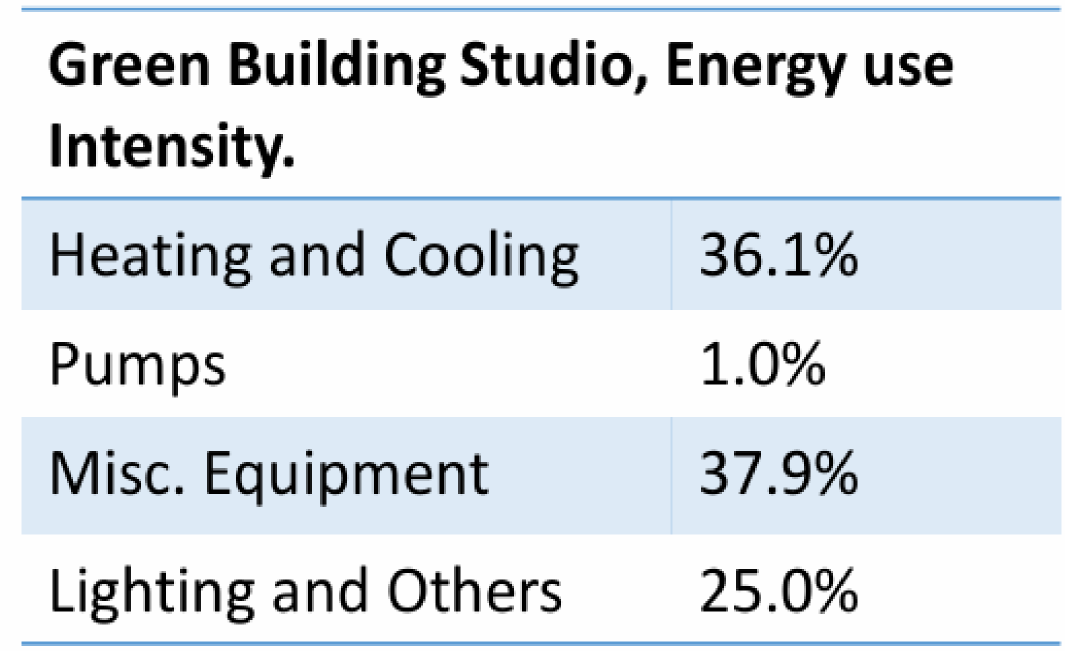
CHAPTER 7 RESULTS AND DISSCUSSION

7.1 BIM Based Analysis, Results and Comparison of Conventional and Sustainable Building Design

7.1.1 Energy Demand of Conventional Buildings by Green Building Studio

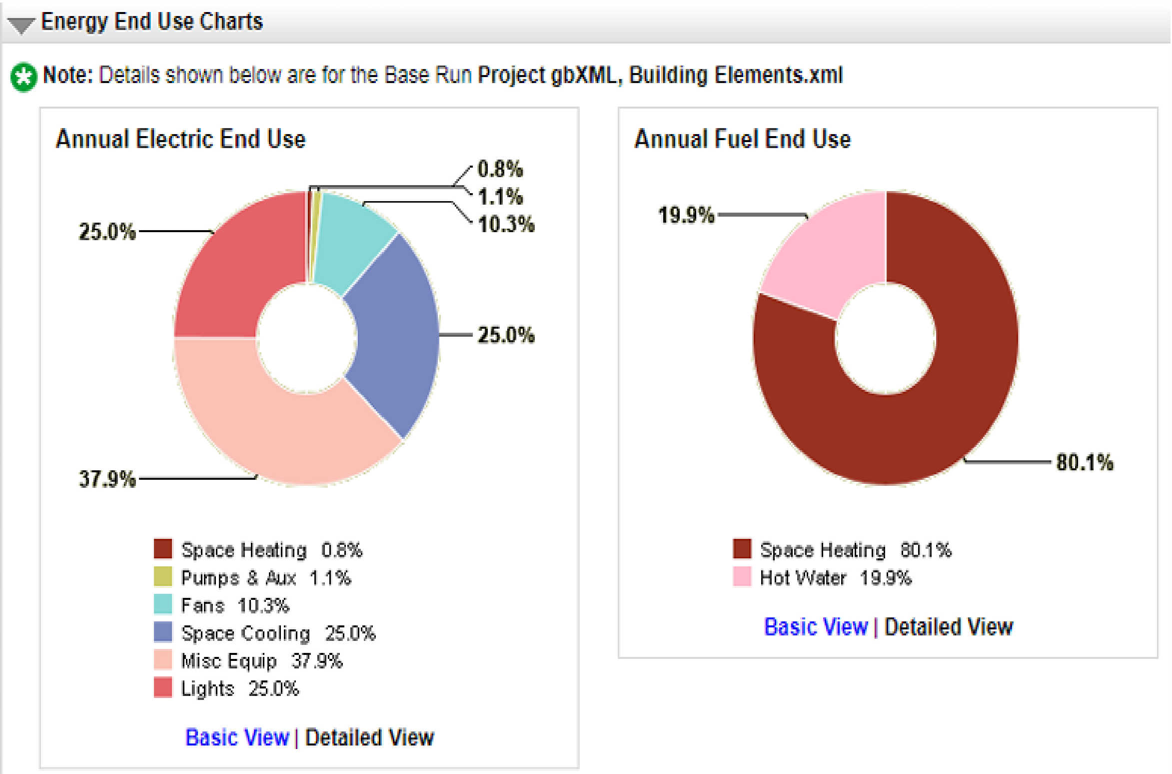
Energy model when uploaded to GBS (Green Building Studio) that analyzed and generated results within an hour depending on extent of the project and inquired options. Generated results were then extracted from the web page of GBS as shown. Results extracted were as followed (table 5 and figure 12):

Table 5 Energy Demand and Results of Energy Analysis by Green Building Studio



Green Building Studio, Energy use Intensity.	
Heating and Cooling	36.1%
Pumps	1.0%
Misc. Equipment	37.9%
Lighting and Others	25.0%

Green Building Studio, Energy Analysis.	
Annual Energy Demand	876,040 kWh
Annual Peak Demand	754.0 kWh
Annual Energy Cost	RS 26,062,190/- @ RS 29.76/- PER kWh



Note: Details shown below are for the Base Run **Project gbXML, Building Elements.xml**

Figure 12 Energy use intensity by GBS

7.1.2 Energy Demand of Buildings after Sustainable Design Alternatives

7.1.2.1 Solar System

A building integrated photovoltaic system was used.

Two trails were conducted:

Trial 1 → Roof Installed Panels   Trial 2 → Façade Installed Panels

Respective trails were made for optimum power generation with minimal Payback period as shown below in table 6.

Table 6 Installed BIPV system statistics.

System Type	Efficiency	Panel Price	Wattage	Qty Installed	Percentage Reduction
Trail 1	7.5%	Rs.32,016.64	40W/m^2	157	48.174%
Trial 2	13.8%	Rs.47,431.96	118W/m^2	276	63.157%

71.2.2 Lighting System

First, we defined three different types of lighting fixtures in Ecotect Material selection library that in Simple ESL (Energy Saving Light), LED (Light Emitting Diodes) and SMD (Surface Mounted Diodes) and analyzed for each against optimal visibility and minimal power consumption that will ultimately reduce the life-time cost. Results in table 7 show that SMD were performing the best of all and easily used with minimal initial cost increase per fixture, but reduction in lifetime cost is significant that is, moving from dry bulb to SMD we were saving almost 88-92.5% in terms of wattage. Results of luminosity analysis are shown in figure 13.

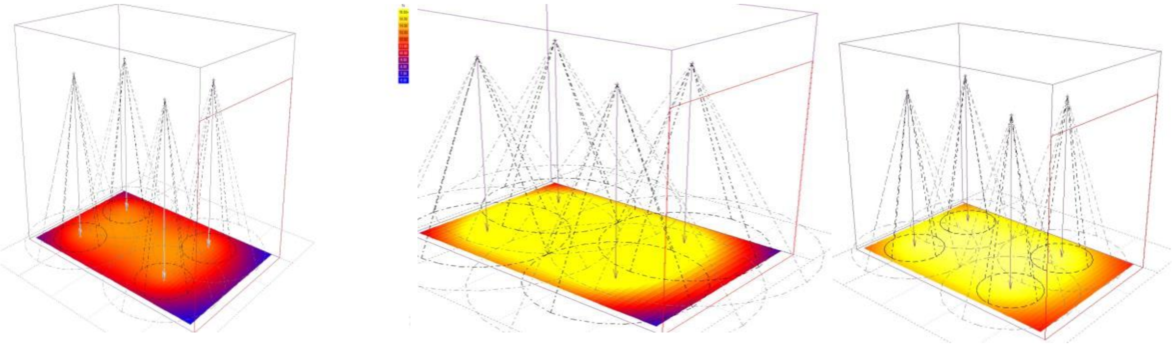


Figure 13 Ecotect luminosity analysis for ESL, LED,SMD.

Table 7 Lumens vs Watts: Output and wattages based on most common products available for each medium screw-based light bulb.

Lumens	**ESL** (Energy Saving Lights)	**LED** (Light Emitting Diodes)	**SMD** (Surface Mounted Diodes)
1600	60 W	up to 22 W	up to 12 W
1100	45 W	up to 18 W	up to 8 W
800	36 W	up to 16 W	up to 6 W
450	25 W	up to 10 W	up to 3 W

7.1.2.3 Passive Techniques

A number of passive energy saving techniques were applied to our case study. The updated model was then uploaded to GBS to calculate the energy consumption of the model. A minimal reduction in energy consumption was seen for individual strategies but when combined, these passive techniques reduced energy consumption by a substantial amount i.e. almost 16%. The results of the analysis are shown below in table 8. Figure 14 shows a few passive strategies applied on a typical building.

Table 8 Reduction in energy use for passive strategies.

SR #	Strategy	Percentage Reduction (%)
1	External wall insulation	5.08
2	Shading	2.86
3	Glazing	2.80
4	Roof insulation	2.59
5	Natural ventilation	2.43
6	Floor insulation	2.24
7	White cool roof	1.71
8	Green roof	0.39
9	Heat pipes	0.86
10	Light reflective paint	1.14
11	Reducing infiltration rate	0.88

7.2 Solid Waste Management

7.2.1 Data Collection

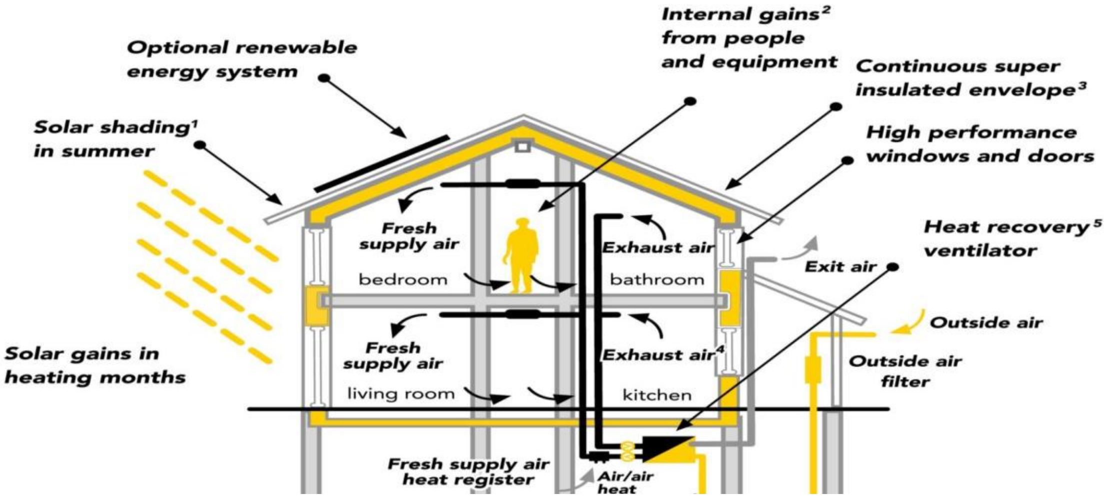


Figure 14 Passive stratigies.

Data collection in solid waste involves systematically gathering information related to various aspects of the waste stream. This process is essential for understanding the composition, characteristics, and trends associated with solid waste. Collection methods may include sampling, where representative samples are collected from different sources within the waste stream to provide a snapshot of overall waste composition. Weighing and volume measurements are conducted to quantify the amount of solid waste generated. Categorization involves classifying waste types, such as organic, recyclable, hazardous, and non-recyclable materials. Visual inspection provides insights into physical characteristics, presence of contaminants, and potential recyclables.

7.2.2 Composition of Solid Waste

After collection of solid waste samples, data compilation was carried out. All the collected data samples were compiled in the form of a pie chart shown in figure 15 and 16.

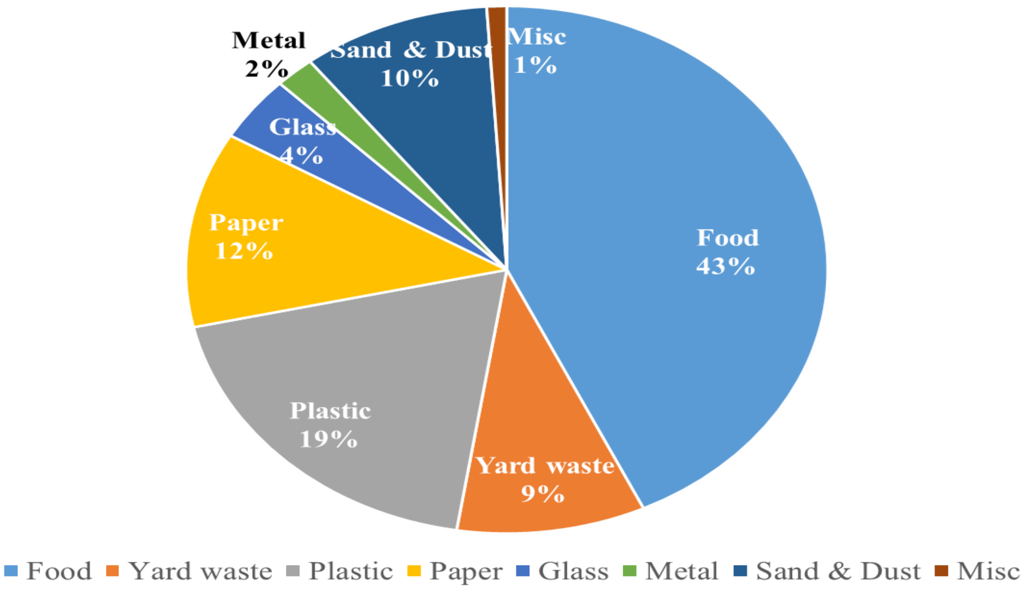


Figure 15 Waste Composition of Cadets Battalion

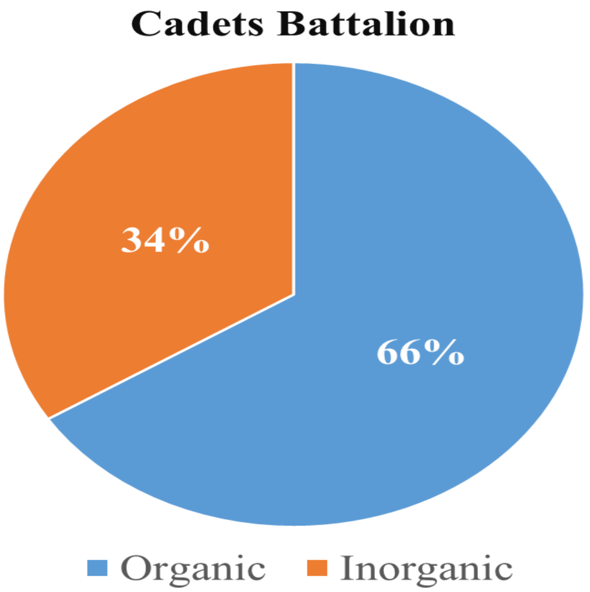
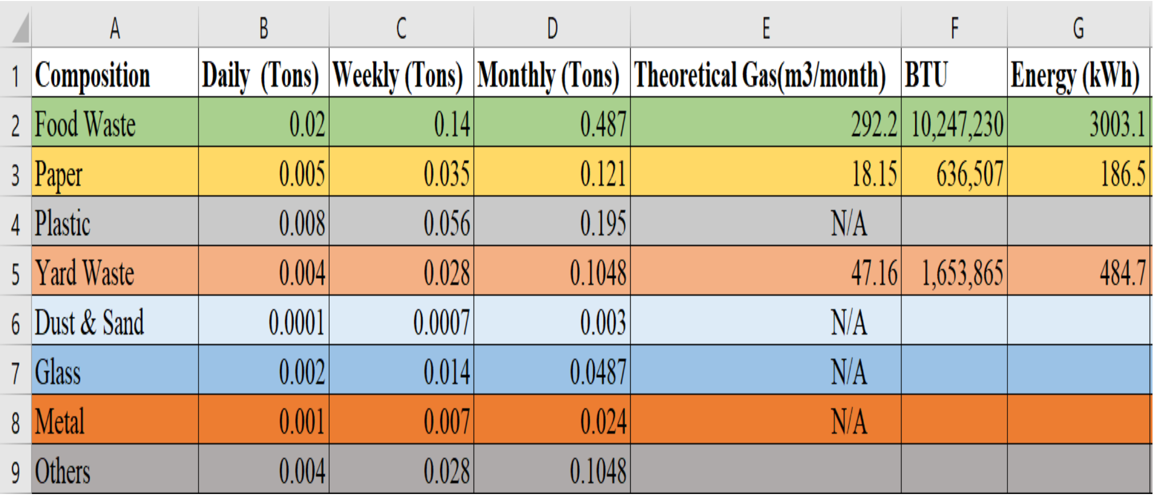


Figure 16 Composition of Organic and Inorganic Waste

7.2.3 Energy Calculations

Assessment of COD, theoretical gas yield, energy and carbon footprints was carried out and the results obtained are as shown below in figure 19.



	A	B	C	D	E	F	G
1	Composition	Daily (Tons)	Weekly (Tons)	Monthly (Tons)	Theoretical Gas(m3/month)	BTU	Energy (kWh)
2	Food Waste	0.02	0.14	0.487	292.2	10,247,230	3003.1
3	Paper	0.005	0.035	0.121	18.15	636,507	186.5
4	Plastic	0.008	0.056	0.195	N/A		
5	Yard Waste	0.004	0.028	0.1048	47.16	1,653,865	484.7
6	Dust & Sand	0.0001	0.0007	0.003	N/A		
7	Glass	0.002	0.014	0.0487	N/A		
8	Metal	0.001	0.007	0.024	N/A		
9	Others	0.004	0.028	0.1048			

Figure 19 Energy Calculation

7.2.4 Estimation of Biogas Yield

Total food waste $= 53{,}880 \ \frac{Kg}{month}$

20 % water moisture in waste $= 10{,}778 \ Liters$

Total inflow $= \ 53{,}890 + 10{,}778$

$$= 64{,}668 \ \frac{liter}{month}$$

CoD of kitchen waste $= 0.242 \frac{Kg}{liter}$

Total CoD of inflow waste $= 0.242 \frac{Kg}{liter} \times 64{,}668 \frac{Liter}{month}$

$= 15{,}650\ Kg = 15.65\ tons$

4 gram of CoD $= 1.4\ Liter\ of\ CH_4$

CH_4 produced from food waste $= 5{,}477{,}500 \frac{Liter}{month}$

$= 5477.5 \frac{m^3}{month}$

7.3 Water Usage Optimization

7.3.1 Rainwater Harvesting

Name of location: Risalpur, Pakistan

Latitude: 34.06400	Longitude: 71.99443

Total yearly rainfall in Risalpur is shown in figure 22 and table 9.

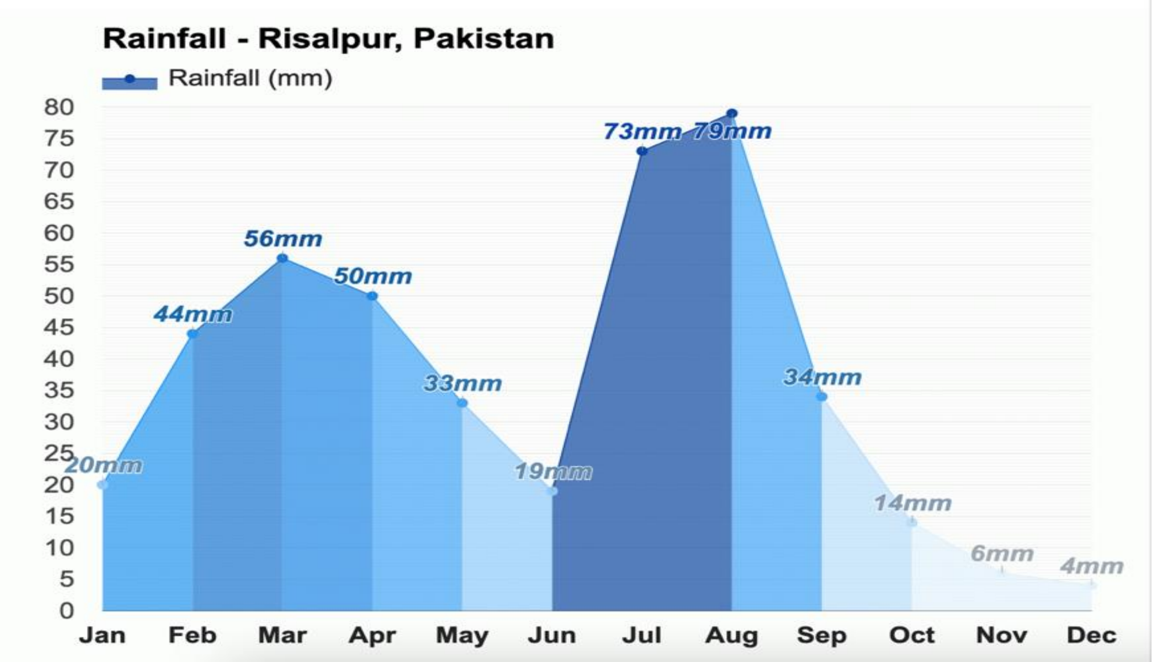


Figure 22 Monthly rainfall data for Risalpur for 2024 (weather atlas)

Table 9 Monthly rainfall data, Risalpur.

MONTH	RAINFALL (mm)	MONTH	RAINFALL (mm)
Jan	20	Jul	73
Feb	44	Aug	79
Mar	56	Sep	34
Apr	50	Oct	14
May	33	Nov	6
Jun	19	Dec	4
Total		**432**	

7.3.1.1 Calculating Runoff

$$Supply\ (S) = Rainfall(R) \times Area(A) \times Run - off\ Coefficient\ (Cr)$$

$$where: \quad S = \ Mean\ annual\ rainwater\ supply\ (m^3)$$

$$R = \ Mean\ annual\ rainfall\ (m)$$

$$A = \ Catchment\ area\ (m^2)$$

$$Cr = \ Run - off\ coefficient$$

$$assume \quad Cr = 0.7\ (for\ ashaltic\ or\ concrete\ pavement\ Cr = 0.7 - 0.9)$$

Targeted area for designing is 900 ft2 piece on the roof of MCE cadet mess.

A= 900ft2= almost 90m2

Mean annual rainfall= 432 mm = .432 m

Run-off=S= R x A x Cr

S= 0.432 x 90 x 0.7

= 27.216 cubic meter

Coefficient for evaporation, spillage and first flush= 0.8

The collection efficiency considers the fact that all the rainwater dripping over a region cannot be effectively reaped because of spillage, evaporation, etc. First flush wastage i.e. first spell of rain is flushed out, spillage and evaporation does not set foot in the system so a constant co-efficient of 0.8 may be taken for all possibilities. This is done because the first spell of rain carries with it a relatively larger number of pollutants from the air and catchment surface.

Amount of rainfall available for use = 27.216 x 0.8

= 21.7728 cubic meter

7.3.1.2 Selection of Catchment Area

Roofs provide a perfect catchment surface for harvesting rainwater, on the condition that they are clean. The roof of MCE cadet mess is a flat cement roof. There is no debris or litter on the roof as it is not easy to access, and litter is considerably less due to the height of the structure.

7.3.1.3 Delivery System

Drainage pipes are usually provided on roofs for storm water. The additional work is to connect that collector pipe to our purification and storage system.

For our case of MCE cadet mess, we will attach PVC pipes with the existing collector pipes and then lead it to the designed filter system and further to the storage tank.

7.3.1.4 First Flush

For 100 square feet area 1 gallon of first flush is required, our targeted area is about 900 square feet, therefore, we will use a container with capacity of 30 liters equivalent to 8 gallons.

7.3.1.5 Selection of Storage Reservoir

Due to adequate storage capacity and fulfillment of our requirements, we have chosen a much easier and conventional method of storage using fiberglass tank of 300-gallon capacity.

7.3.1.6 Benefits of Design

1. **Water Security**: RWH ensures a reliable water supply, reducing dependency on external sources during water scarcity.
2. **Cost Savings**: It significantly reduces operational costs by utilizing harvested rainwater for various purposes.
3. **Environmental Sustainability**: RWH minimizes ecological impact by conserving natural resources and reducing strain on local water ecosystems.
4. **Climate Resilience**: It enhances resilience to climate change by providing a buffer against water shortages during adverse weather conditions.

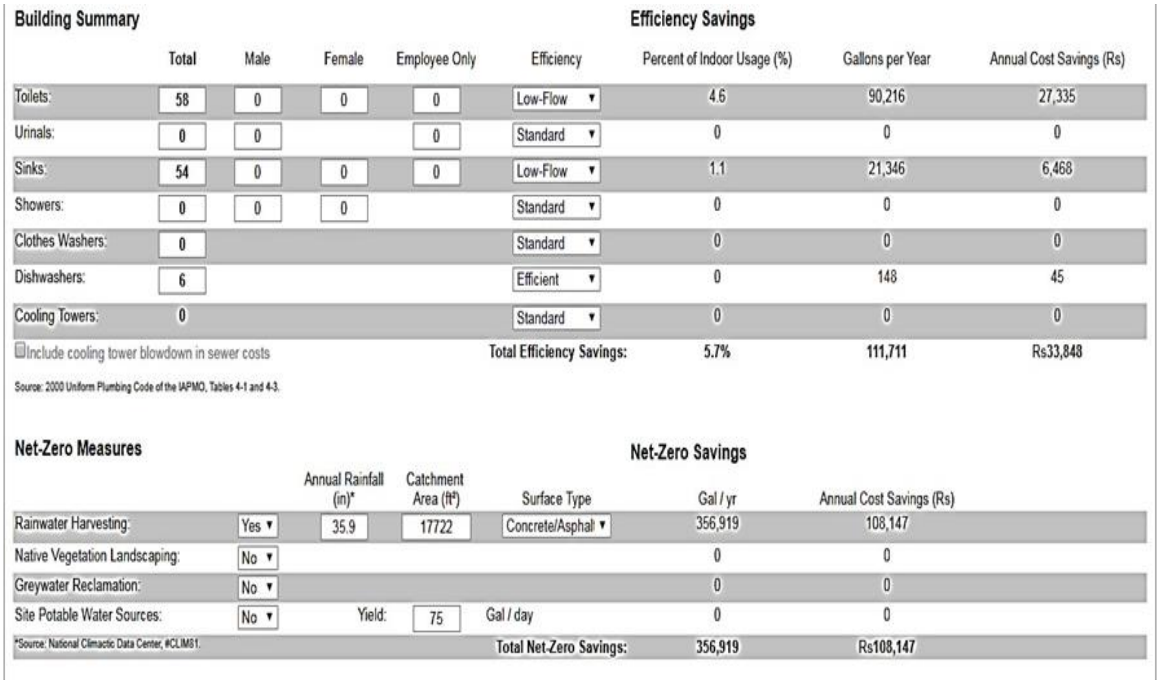
7.3.2 Low Flow Regulators

To have an additional task with our project we decided to go to check our model for the water efficiency too using green building studio. We first analyzed conventional model for water usage as follows and then applied the changes of controlled water usage and rain harvesting as secondary for our proposal that has effects as shown below in table 10and figure 27.

Table 10 Yearly water consumption.

Total Gals / Yr	Indoor Gals / Yr	Outdoor Gals / Yr
1,934,797	1,852,895	81,902

Figure 27 Water Usage by GBS.



Building Summary **Efficiency Savings**

	Total	Male	Female	Employee Only	Efficiency	Percent of Indoor Usage (%)	Gallons per Year	Annual Cost Savings (Rs)
Toilets:	58	0	0	0	Low-Flow ▾	4.6	90,216	27,335
Urinals:	0	0		0	Standard ▾	0	0	0
Sinks:	54	0	0	0	Low-Flow ▾	1.1	21,346	6,468
Showers:	0	0	0		Standard ▾	0	0	0
Clothes Washers:	0				Standard ▾	0	0	0
Dishwashers:	6				Efficient ▾	0	148	45
Cooling Towers:	0				Standard ▾	0	0	0
☐ Include cooling tower blowdown in sewer costs					**Total Efficiency Savings:**	**5.7%**	**111,711**	**Rs33,848**

Source: 2000 Uniform Plumbing Code of the IAPMO, Tables 4-1 and 4-3.

Net-Zero Measures **Net-Zero Savings**

		Annual Rainfall (in)*	Catchment Area (ft²)	Surface Type	Gal / yr	Annual Cost Savings (Rs)
Rainwater Harvesting:	Yes ▾	35.9	17722	Concrete/Asphal ▾	356,919	108,147
Native Vegetation Landscaping:	No ▾				0	0
Greywater Reclamation:	No ▾				0	0
Site Potable Water Sources:	No ▾	Yield:	75	Gal / day	0	0
*Source: National Climactic Data Center, #CLIM81.				**Total Net-Zero Savings:**	**356,919**	**Rs108,147**

After using Low-Flow Regulators for Toilets and Sinks Saving in terms of Percentage of Gallons was turned out to be 5.7%. Low Flow valves are control valves and regulators designed for low flow applications. A flow regulator restricts and reduces the amount of liquid flowing through a pipe thus saving a substantial amount of water.

CHAPTER 8: CONCLUSION AND RECOMMENDATIONS

8.1 Conclusions

a) The best possible System Design by Our Analysis was Exterior of Building was almost fully covered with solar panels.

b) By using LEDs instead of ESLs, the decrease in electricity is almost 40-60% and replacing ESLs with SMDs we had savings of up to 80% of electricity.

c) We have shifted our major appliances to solar panels. The initial cost is high, but payback time is about 11.9 years with Lifetime cost savings of about 800 million.

d) By using passive energy reduction strategies, almost 16% energy consumption is reduced.

e) By recycling organic waste, we can generate 44088 kWh of energy per year.

f) With the help of rain harvesting almost 900 Gal/yr can be utilized for gardening and drains purposes.

8.2 Recommendations

a) Conduct comprehensive life cycle assessments to evaluate the environmental impacts of building materials, and operational strategies.

b) Research on actual field performance of different construction materials and other home utility products must be carried out.

c) A comprehensive study at a broader level on Risalpur Cantt should be done.

d) Wastewater treatment systems can be incorporated to harness energy from water waste.

e) The effect of plantation on infrastructure can be studied.

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Sustainable Infrastructure Design Using BIM

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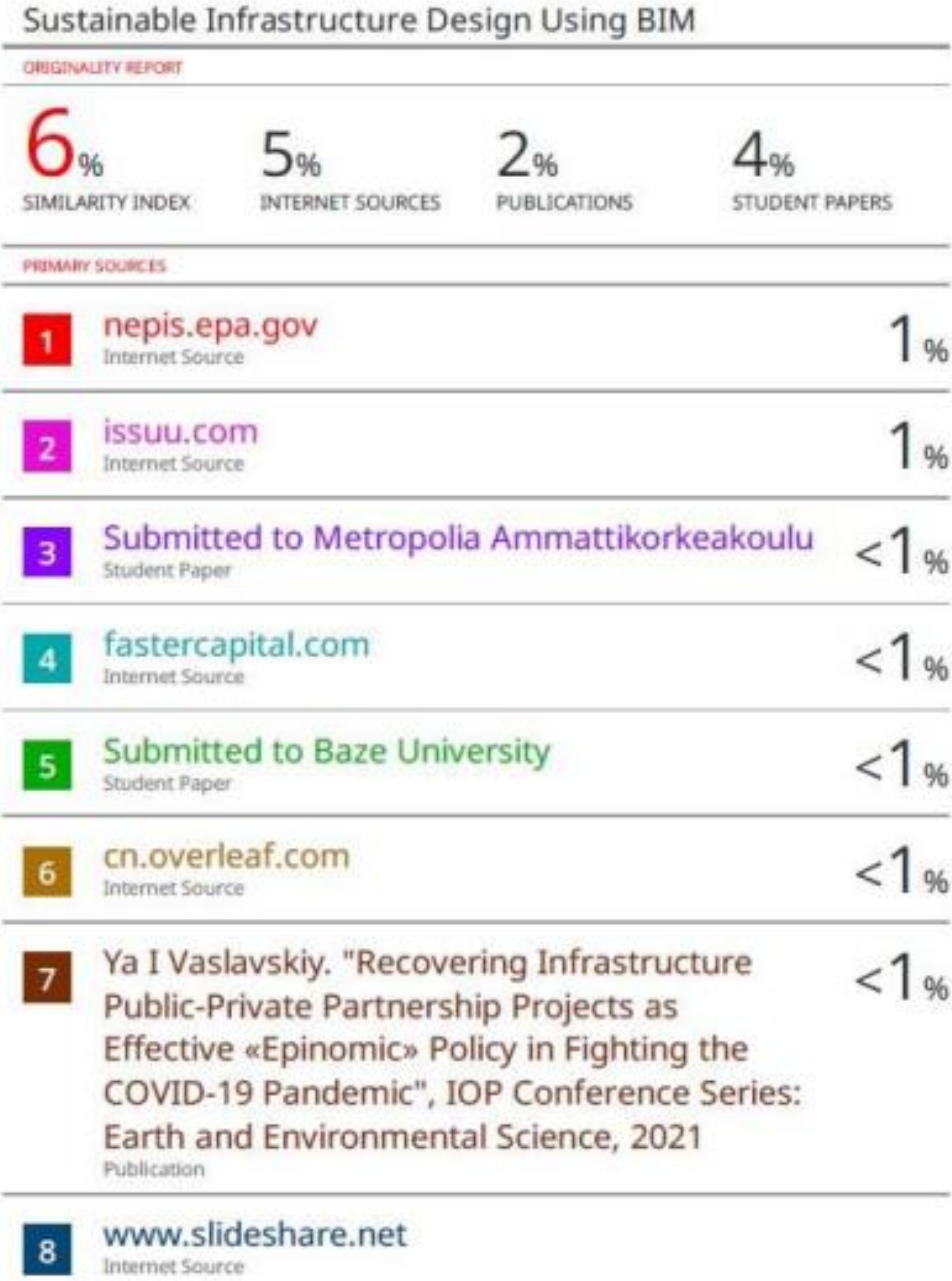

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