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Analysis of Existing Situation and Opportunities in Building Design – Architectural Expert

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TABLE OF CONTENTS

1. INTRODUCTION

PURPOSE OF THE REVIEW AND ANALYSIS

The purpose of this review and analysis is to comprehensively examine the current state of building design practices in Pakistan, with a focus on identifying existing situations, challenges, and opportunities within the construction sector of the country. The analysis focuses mainly on residential, commercial, and public buildings in Pakistan. Through a thorough examination of relevant literature, industry trends, and case studies, this document seeks to provide a detailed assessment of the key factors influencing current building design in Pakistan such as building orientation, window-to-wall ratio (WWR), biophilic design elements, and renewable energy integration. By doing so, it aims to shed light on the strengths and weaknesses of existing approaches, pinpoint areas in need of improvement, and uncover opportunities for improvement. The value of the design phases is given below in Figure 1, the analysis is conducted keeping the value chain under consideration.

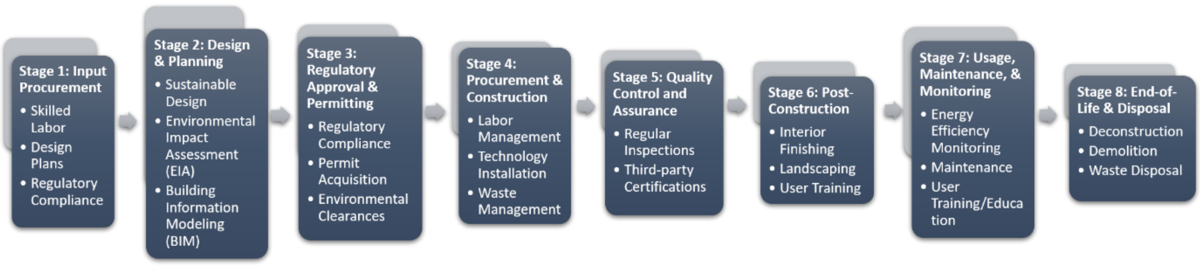

Figure 1- Value Chain Analysis of the Design Phases of Green Buildings in Pakistan

This analysis will serve as a valuable resource for architects, designers, and stakeholders in the construction industry of Pakistan, enabling them to make informed decisions and strategically leverage emerging trends to enhance future building designs' efficiency, sustainability, and functionality.

BACKGROUND (PAKISTAN INFRASTRUCTURE AND GREEN BUILDINGS)

Pakistan is rapidly becoming more urbanized, expecting more than 40 million additional people to reside in urban areas by 2025 due to better living standards and the availability of more job opportunities in urban areas. Pakistan has consistently faced an energy crisis due to high demand during peak summer months and inadequate electricity supply. Many regions in the country experience temperatures exceeding 40 degrees Celsius during summers which leads to extensive use of air conditioners and other cooling appliances increasing the energy demand of the country in summer. This requires the country to prioritize demand-side management and energy cost-saving design practices.

Efforts are needed to improve building design, internal conditions (heating and cooling), energy consumption, and energy efficiency and to reduce the overall environmental impact, which is where green buildings come in. Green building design offers a lot of benefits from an architectural and design perspective. Architects and designers focus on energy efficiency by incorporating features such as well-insulated walls, natural ventilation, and efficient heating, ventilation, and cooling systems (HVAC), which not only reduce utility costs but also lower the building's environmental footprint. These designs also emphasize occupant health and well-being, utilizing low-VOC (Volatile Organic Compound) materials and proper indoor air quality measures to create comfortable and healthy indoor environments. Additionally, green building designs often draw inspiration from nature, leading to aesthetically pleasing structures that harmonize with their surroundings and mitigate the urban heat island effect.

Implementing green architecture in Pakistan will lead to many different areas which the country can benefit from such as energy conservation through energy-efficient building design features and the incorporation of renewable energy systems into the building design to reduce the use of non-renewable sources of energy that leads to a reduction in the carbon footprint of the building. Analysis of the current situation is required to better understand the challenges and opportunities in green buildings from a design perspective in Pakistan.

2. PRESENT SITUATION

Pakistan has a rich culture and traditional infrastructure such as traditional mosques, forts, and shah gardens. This document however focuses on three major types of buildings that currently exist in the country:

- **Residential Buildings:** Residential buildings in Pakistan vary from modern urban apartments to traditional rural houses with courtyards. These prioritize comfort and privacy, with diverse room types and materials ranging from brick and mud to concrete and steel.
- **Public Buildings:** Public buildings in Pakistan, such as government offices, schools, hospitals, religious structures, and transportation hubs, often reflect cultural and historical contexts, accommodating large crowds with spacious interiors and accessibility features.
- **Commercial Complexes:** Commercial buildings, including offices, retail stores, malls, hotels, restaurants, and warehouses, have architectural styles that reflect branding, with modern designs in urban areas and traditional elements in older structures.

The building sector is responsible for most of the energy consumption in Pakistan, with the residential sector currently being the largest in energy consumption consuming about 49.2%, and the commercial sector consuming about 7% of the total electricity produced in the Country.[1] With a constantly increasing population and urbanization rate, demand for this sector is expected to rise even further. Therefore, it is important to introduce energy-efficient design techniques that can overcome the increase in the energy consumption of buildings in Pakistan.

BUILDING CODES AND LEGISLATION

The government of Pakistan has acknowledged the significance of sustainable building design and has taken measures to encourage its adoption. An illustration of this commitment is the establishment of the Pakistan Green Building Council (PGBC) in 2012, dedicated to advancing sustainable building design and construction practices in the country. As an esteemed member of the World Green Building Council, the PGBC strives to foster a sustainable built environment in Pakistan by advocating for green building approaches. Additionally, the Pakistan Engineering Council's (PEC) 2021 building codes emphasize key architectural considerations, including ventilation, lighting, and roof drainage. These guidelines stress the significance of natural ventilation in occupied spaces, with provisions for accessible windows, doors, louvers, or other openings to the outdoors. When air infiltration rates are low, compliance with the International Mechanical Code is required. The NEECA National Energy Conservation Code 2023 also mentions specific guidelines on sustainable building design practices, such as Green roofing, Window-to-Wall Ratio, Orientation, and integration of Renewable energy, while focusing on the energy saving that these design features can bring. Adequate lighting, both natural and artificial, is mandated to ensure safety and comfort, achieved through strategic design and illumination systems. Biophilic design elements such as green roofs are essential for rainwater management and must adhere to specified standards to safeguard the building's structural integrity and longevity. These comprehensive regulations prioritize the creation of healthier, more functional, and sustainable building environments while enhancing occupant well-being.

Pakistan is lacking in the implementation of these building codes and regulations. Reasons include lawlessness, lack of awareness of the general public on the benefits of green design and workforce on building codes related to design, green design technology unavailability in the country, and financial issues that lead to low or no investment in energy-efficient design features such as integration of renewable energy.

Green building design offers a lot of benefits in terms of cost saving, energy efficiency, and environmental benefits by only incorporating a few changes into the building design, orientation, and architecture. In terms of energy saving, the building sector offers a potential of 30%,[2] which is why Pakistan needs to shift towards green building design by addressing all the gaps that are present in the construction sector. A detailed analysis of the green building design aspect in Pakistan is necessary to utilize the energy and cost savings potential that the building sector has to offer.

1 https://unfccc.int/documents/470405 (BUR1)

2 Baig, A. (2018). *Green Buildings as a Solution for Sustainable Housing: Role of Private Housing Schemes, Lahore, Pakistan*. Research Gate. https://www.researchgate.net/publication/327267222_Green_Buildings_as_solution_for_Sustainable_Housing_Role_of_Private_Housing_Schemes_Lahore_Pakistan

3. ARCHITECT ANALYSIS

Architects are responsible for planning and implementing building design during the construction phase of a building. This section analyses building design in Pakistan from an architectural point of view.

ARCHITECTURAL DESIGN REVIEWS

Architecture plays an important role in the energy efficiency, building aesthetics, and health of the inhabitants through a focus on certain areas such as building orientation, window-to-wall ratio, and energy-efficient building features.[3] The current building design practices in Pakistan will be discussed in the architectural design reviews segment along with suggestions for improvement in design practices.

EVALUATION OF BUILDING DESIGN CONCEPT

Building design in Pakistan is intertwined with the architecture of the broader Indian subcontinent. The major architectural styles popular in the past were Temple, Indo-Islamic, Mughal, and Indo-Saracenic architecture, all of which have many regional varieties. Urban areas of Pakistan are moving towards modern architecture that focuses more on the aesthetics of the building and rural areas have the traditional building style that focuses on the use of natural materials and design elements such as mud, clay bricks, and openings for passive energy use in a building.

Residential building design practices in Pakistan are rather purely traditional or purely modern which can be seen from the study conducted in Lahore, where the two building styles (Figure 2 and Figure 3) were compared to observe the overall design.[4] After comparing both buildings, it was seen that neither traditional nor modern house designs in Lahore are inherently better than the other. Each has its merits based on environmental considerations, for example, traditional houses involve more nature-based elements that help in reducing GHG emissions and providing a healthy environment, and on the other hand, modern buildings focus on the inclusion of renewable energy sources into the building design which reduces their reliance on fossil fuel-based energy.

However, a balanced approach that combines traditional and modern elements, such as the use of eco-friendly design features, utilization of passive energy for lighting and heating purposes, inclusion of renewable energy design systems, and good aesthetics can create a rich house design, preserving heritage while improving energy efficiency, improving heating and cooling mechanisms, and providing good environmental benefits.

3 https://en.wikipedia.org/wiki/Pakistani_architecture#:~:text=Pakistani%20architecture%20is%20intertwined%20with,which%20have%20many%20regional%20varieties.

4 QURESHI, R.A. (2011) *THE TRADITIONAL COURTYARD HOUSE OF LAHORE: AN ANALYSIS CONCERNING DEEP BEAUTY AND SUSTAINABILITY*, *Thesis*.

Figure 2 - Traditional House

Figure 3 - Modern House

Commercial buildings in Pakistan majorly follow modern architecture neglecting sustainable design features into the building. However, some examples exist, such as the Telenor 345 Head office (Figure 4 and Figure 5) located in Islamabad, which is a good example of green architecture. The building has natural airflow through the use of meshes, the orientation of the building is such as to reduce the overall energy consumption and use natural light as much as possible. The design is also highly energy efficient with active chilled beams, LED lights, thermal insulation, and occupancy sensors. The Telenor 345 Head Office was found to have achieved **up to 13% of energy cost savings** and 11% of its energy consumption was shifted to solar energy.[5]

Figure 4 - Telenor 345 Head Office, Islamabad, Pakistan

Figure 5 - Drone view of Telenor 345 Head Office

Green architectural practices can play an important role in energy conservation and GHG emissions reduction. The cost-saving potential of green building design features can be assessed from the study focused on residential buildings in Pakistan. The analysis of conventional buildings shows that a major heat loss of 29.3 kWh/m^2 and 18.3 kWh/m^2 takes place across external walls and roofs respectively while a loss of 5.2 kWh/m^2 was observed through windows. Commutatively, the annual heating demand of conventional buildings was calculated to be 44.2 kWh/m^2 but for energy-efficient buildings, with design features such as building orientation, window-to-wall ratio, nature-based solution, and renewable energy, the losses were significantly reduced consequently leading to 1/10th of annual

5 https://www.telenor.com/binaries/investors/reports-and-information/annual/annual-report-2022/Annual%20Report%202022.pdf

energy demand. For **annual heating, a 32 % energy improvement** was observed while for **cooling, a 38% energy improvement** was observed.[6]

The analysis of the building design concept in Pakistan shows that building design practices are different in urban and rural areas and green architectural practices are not very common in the country but the potential savings can be seen from the analysis and should be utilized. There are some good examples such as the Telenor 345 Head Office, which can be set as a best practices example to follow in residential areas as well. There is still a need for improvement in different areas of green design in Pakistan, which needs to be addressed.

Areas of Improvement

The following possible options were identified which Pakistan can implement to make good progress in green architecture:

1. Balanced Approach to Traditional and Modern Design: Traditional designs in Pakistan focus fully on natural lighting, passive heating, and cooling, which leads to energy efficiency, but the aesthetics and incorporation of technology in the building are overlooked. On the other hand, modern buildings focus more on aesthetics and the latest technology, and other factors such as passive energy use and the incorporation of nature-based elements are overlooked. Building design features such as natural lighting and airflow, integrating modern technology such as renewable energy along with nature-based solutions, and overall good aesthetics can be used together for a green building design in Pakistan. This design practice is not only for residential buildings, it can be implemented for commercial, and public buildings as well.

2. Awareness of the Public: The local community in Pakistan does not pay much attention to building design aspects during the planning or construction phase of a building which is due to a lack of awareness of the benefits of green building design. The government can take initiatives for capacity building of the general public as well as the workforce including training sessions and workshops on the negative impacts and benefits of using green design features.

3. Implementation of Building Codes: Building codes exist in Pakistan such as PEC Building Codes 2021 and NEECA National Energy Conservation Code 2023, which contain detailed segments on the architecture and design-related aspects of buildings but they lack implementation which is where Pakistan is struggling to move towards green buildings. The government should ensure enforcement of these codes through dedicated departments, capacity building should be done for the stakeholders involved.

6 M. Mahboob, T. u. Rashid and M. Amjad, "Assessment of Energy Saving Potential in Residential Sector of Pakistan through Implementation of NEECA and PEC Building Standards," *2019 15th International Conference on Emerging Technologies (ICET)*, Peshawar, Pakistan, 2019, pp. 1-6, doi: 10.1109/ICET48972.2019.8994750.

BUILDING ORIENTATION AND WINDOW-TO-WALL RATIO (WWR)

Building orientation and window-to-wall ratio (WWR) play a vital role in the overall energy use of the building as they can provide options for passive heating in winter, and use of wind in summer, and increasing the window-to-wall ratio decreases the lighting demand of the building.

ASSESSMENT OF ORIENTATION'S IMPACT ON BUILDING PERFORMANCE

Concepts like building orientation are often overlooked during the construction of residential public or commercial buildings in Pakistan due to a lack of awareness of the architect and the general public. According to NEECA National Energy Conservation Building Code 2023, a compact building shape and appropriate building orientation can reduce the energy consumption for heating and cooling systems by up to 50% to 80% depending on the geographical conditions where the building is located. The identification of such an improvement in building codes is not enough unless these codes are disseminated widely and backed with information on the long-term economic benefits for dwellers. Along with this, the government’s role in the early adoption of these practices is pivotal.

The concept of building orientation in residential, public, and commercial buildings in Pakistan is not very common but there are some examples in Pakistan where building orientation was considered during design. A study was done for a public building (Mosque) in Pakistan, where Faran mosque located in Karachi was analyzed from the building orientation perspective and it was found that the overall design and orientation facilitated the building wind flow and use of natural light which improved the energy efficiency of the building by reducing the use of appliances for cooling and heating. Sprinklers were also used in the building which were placed in the windward direction to maintain a cool temperature in summers.[7] Using passive sunlight and natural wind flow reduces the overall energy use and improves the building's air quality as well in all seasons.

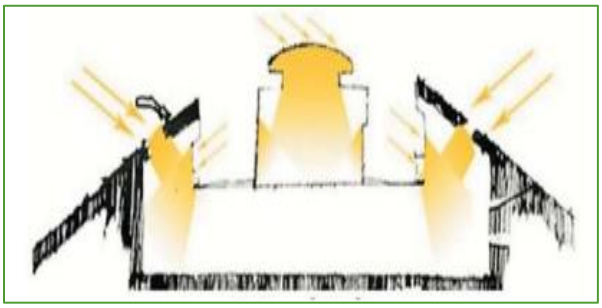

Figure 6 - Section showing light paths into the mosque[6]

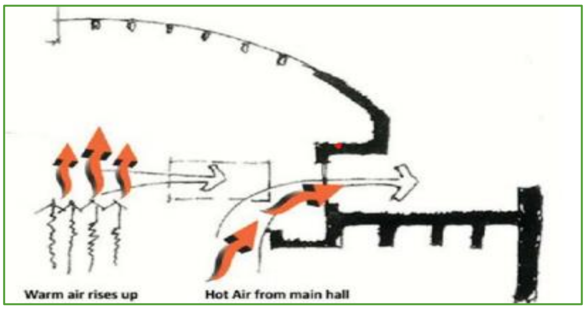

Figure 7 - Wind flow inside the mosque[6]

Pakistan can also take the concept of building orientation from the best practices in other parts of the world. In Iraq, a study was conducted using BIM (Building Information Modelling) in which different types of building shapes and orientations were simulated using an application called Revit, which showed that the T-shape model is the least consuming energy model at a rotation angle of 285˚, as its energy consumption amounted to 40,495 kWh for 964$ per year.[8] The U-shape model is one of the

7 Naqvi, Z.A. and Asghar, Q. (2020) *Architectural Analysis: distinctive building features in Pakistani architecture*, *Journal of Research in Architecture and Planning*. Available at: https://www.academia.edu/43730064/Architectural_Analysis_Distinctive_Building_Features_in_Pakistani_Architecture

8 Qubad Sabah Haseeb, Sumbul Muhammed Yunus, Anas Attellah Ali Shoshan, Adil Ibrahim Aziz,
A study of the optimal form and orientation for more energy efficiency to mass model multi-story buildings of Kirkuk city, Iraq, Alexandria Engineering Journal, Volume 71, 2023, Pages 731-741, ISSN 1110-0168, https://doi.org/10.1016/j.aej.2023.03.020.

most energy-consuming at the angle of rotation is 270˚, where its energy consumption amounted to 73,880 kWh at a cost of 1758$per year, which equals almost 56% difference in the overall energy cost of both models, keeping other properties such as area and capacity the same. [9]

Name of shape	letter T	letter U	inner courtyard	letter L	square	rectangle
shape						
sample	A1	A2	A3	A4	A5	A6

Figure 8. Shapes of Models

Building orientation plays a key role in the energy cost-savings of a building. A study done in Egypt shows that a building oriented with a south facade can save energy costs up to 26% over a building with a western facade.[10] According to the Bonneville Power Administration and the City of San Jose, California, homes re-oriented toward the Sun without any additional solar features save between 10% and 20% in cold regions and some can **save up to 40% in hot regions**.[11] Another study in Jamaica shows that correctly oriented buildings can save up to **30-40% of their electricity**.[12]

Further, the cost savings will calculated by using the annual utility expenses in Pakistan. The utility expenses in Pakistan vary from season to season. The average household electricity bills in Pakistan based on an evaluation for the year 2022 are as low as 2000-3000/- PKR in winter and in the Summer season, as electricity consumption increases, the electricity bills can go up to 7,000/- PKR. [13] It was analyzed that an average of 30% cost savings in summers and 15% in winters, can be achieved from building orientation alone. [14] The following is a calculation of the total cost savings that can be achieved through the use of proper orientation in buildings in Pakistan:

Table 1 - Cost Savings due to building orientation in an Average Household in Pakistan

Season	Average Household Electricity Cost (PKR)	Percentage Savings (%)	Cost after Orientation Correction (PKR)	Cost Savings (PKR)
Winter	3000	15	2550	450
Summers	7000	30	4900	2100

9 Qubad Sabah Haseeb, Sumbul Muhammed Yunus, Anas Attellah Ali Shoshan, Adil Ibrahim Aziz,
A study of the optimal form and orientation for more energy efficiency to mass model multi-story buildings of Kirkuk city, Iraq, Alexandria Engineering Journal, Volume 71, 2023, Pages 731-741, ISSN 1110-0168, https://doi.org/10.1016/j.aej.2023.03.020.

10 Elghamry, Rania & Azmy, Neveen. (2017). Building orientation and its impact on energy consumption. Available at https://www.researchgate.net/publication/327623184_Buildings_orientation_and_it's_impact_on_the_energy_consumption

11 https://www.nachi.org/building-orientation-optimum-energy.htm

12 https://buildbetterja.com/

13 https://www.graana.com/blog/cost-of-living-in-pakistan/#:~:text=Utilities%20(Monthly)&text=2000%2D3000%20in%20winter%20(October,7%2C000%20(%2445)%20plus.

14 https://www.graana.com/blog/cost-of-living-in-pakistan/#:~:text=Utilities%20(Monthly)&text=2000%2D3000%20in%20winter%20(October,7%2C000%20(%2445)%20plus.

The calculation shows that a maximum energy cost savings can be **2,100/- PKR per month in Summer** and **450/- PKR per month in winter** in an average household thus energy cost savings can be achieved by orienting the building properly. The cost-saving opportunity should be utilized in Pakistan to relieve the economic stress of utilities of the homeowners.

The Government acknowledges the importance of building orientation in a building design, which is why building codes contain guidelines on building orientation. According to the NEECA Energy Conservation Building Code 2023, the longer axis of any commercial, residential, or public building should not face east or west as they receive constant sunlight at a low angle all over the year and summers can be very difficult for the inhabitants of the building.

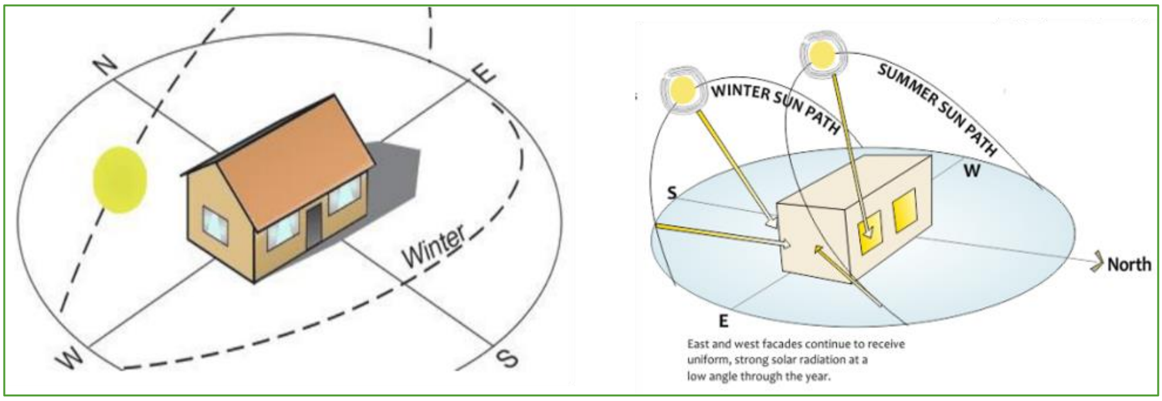

Figure 9 – Longer side of the building should be towards north and south (NEECA)

Overall, it can be seen that Pakistan is lacking in building design from the perspective of building orientation which can reduce energy costs by up to 30% in summers and winters, and maintain healthy internal conditions with good air flow. Building codes do exist in this area but they have improper implementation which can be ensured to cater to this issue.

Areas of Improvement

1. Best Practices as an Example: Faran Mosque in Karachi, as explained in section 3.2.1, is a very sound example of how the building should be oriented to utilize passive sunlight and maintain good airflow during hot seasons. Practices like this need to be promoted and discussed frequently in Pakistan by organizing training programs for the public and professionals, collaborating with universities for workshops and seminars for youth, and carrying out demonstration projects to make the engineers, architects, laborers, and the public aware of these factors.

2. Climate-Responsive Design: Architects should be encouraged by providing incentives, recognition, training programs, and regulatory support to adopt climate-responsive design strategies, such as the use of sun shades, overhangs, and windbreaks, to harness sunlight for passive heating in winter while minimizing heat gain in summer. These features can significantly contribute to overall sustainability.

3. Promote the Use of Simulation Tools: The case studies used in the analysis involved the use of a simulation tool such as Revit for analyzing the impacts of the building orientation on energy cost savings. The use of such software should be normalized and architects and engineers should be proficient in using this kind of software, which can help them build and design better.

4. Lack of implementation in Building Codes: A Detailed Energy conservation building Code exists as mentioned earlier on how the building shall be oriented to improve energy efficiency but it lacks implementation at the local level due to low awareness of the general public and labor. If the NEECA Energy Building Code 2023 guidelines are followed, it can decrease the energy demand and cater for a large portion of the energy shortage by only improving the building orientation. The government should ensure the implementation of building codes to make Pakistan shift towards green design.

ANALYSIS OF WINDOW-TO-WALL AREA RATIO ON ENERGY PERFORMANCE OF THE BUILDING

Around 50% of the energy that buildings lose goes through their windows. The best WWR is the amount of window space that uses the least energy over the entire year for cooling, heating, and lighting. The window-to-wall area ratio (WWR) is a critical factor in building design, especially in the context of achieving optimal daylighting and energy efficiency in Pakistan. The baseline WWR[15] in residential buildings in Pakistan showing an average **WWR of 20%** as used in a study is given below:

Table 2 - Baseline Window-to-Wall Ratios in Residential Buildings in Pakistan

Walls	Baseline Windows Area
East Wall	0%
West Wall	17.50%
North Wall	22.30%
South Wall	27%

The high cost of electricity is a major issue in Pakistan and the demand for artificial cooling systems is increasing in Pakistan, which was analyzed in an example where in commercial complexes in Lahore, a study was conducted due to the increase in the demand for cooling appliances. [16] It was analyzed by using a simulation software called “COMFEN” that WWR and heat gain are in a linear relation with each other and an average WWR of 20-30% showed a reduced amount of heat gain while keeping the required amount of passive lighting to the building of the commercial buildings. A public sector building i.e., PAK Secretariat, was analyzed for the impacts of WWR on energy savings and it showed a **286.7 kWh in annual energy savings** when the WWR was reduced from **38% to 33%**. The cost of the

15 Ahmad, Khurshid, et al. “Effect of Windows Area Reduction and Glazing Type on Energy Consumption of Residential Buildings in Islamabad.” *Research Gate*, 2012, www.researchgate.net/figure/2-Window-to-wall-percentages-of-residential-building_tbl1_262449976.

16 Rasheed, M. (2016). Effect of Window Wall Ratio (WWR) on heat gain in commercial buildings in the climate of Lahore. https://www.researchgate.net/publication/307863044_Effect_of_Window_Wall_Ratio_WWR_on_heat_gain_in_commercial_buildings_in_the_climate_of_Lahore

energy savings comes out to be **12,328/- PKR per year**,[17] which is not a huge cost saving but it can be improved by further improving the WWR. [18]

Further, energy cost saving through the optimization of the window-to-wall ratio can also be seen from the example where BIM was used to optimize the WWR from an average of 40-45% to **an average WWR of 25-30%**. The study shows that there was a decrease in the mean energy cost from the **cost of 229 kWh/m^2/year to the cost of 160 kWh/m^2/year** for the residential building, which equals a **reduction of 30%** in the energy costs. [19]

The energy cost savings of a building due to the optimization of the WWR from 28% to 14% were found to be **9.4% to 13.3% in cold regions** and **34.3% to 44.2% in hot regions** due to a major reduction in the use of air conditioning systems. [20] An average of these cost-saving ranges can be used to calculate the cost savings in an average household in Pakistan by using the average utility expense in a building. The following is a calculation of energy cost savings in the average household in Pakistan:

Table 3 - Cost Savings Due to WWR in an Average Household in Pakistan

Season	Average Household Electricity Cost (PKR)	Percentage Cost Savings (%)	Cost after optimizing WWR (PKR)	Cost Savings (PKR)
Winter	3000	11.5	2655	345
Summer	7000	39.5	4250	2750

It can be seen that in winter, an energy **cost saving of 345/- PKR per month** can be achieved, and on the other hand, a substantial **cost saving of 2,750/- PKR per month** can be achieved by optimizing the WWR of a building. These benefits are recognized by the Government of Pakistan, which is why building codes contain guidelines on these design elements. The Energy Conservation Building Code 2023 contains a detailed section on the WWR by the Solar Heat Gain and Solar Glazing Coefficients but it lacks implementation due to the low awareness of the public and professionals and also low or no use of simulation software by architects or engineers in the planning phase of the building.

Hence WWR can have a good impact on the energy performance of a building while also ensuring the effective use of passive sunlight and air flow into the building. WWR has a linear relation with the heat gain of a building leading to an increased use of cooling appliances in the summer. However, It can lead to cost savings of up to 2,750/- PKR per month in summer, and 345/- PKR per month in winter for

17 Masood, A. K. (2014). *Impact of windows to wall ratio on energy consumption in building …* Research Gate. https://www.researchgate.net/publication/308731869_Impact_of_windows_to_wall_ratio_on_energy_consumption_in_building_sector_of_Pakistan

18 Rasheed, M. (2016). Effect of Window Wall Ratio (WWR) on heat gain in commercial buildings in the climate of Lahore. https://www.researchgate.net/publication/307863044_Effect_of_Window_Wall_Ratio_WWR_on_heat_gain_in_commercial_buildings_in_the_climate_of_Lahore

19 Zhang, J., Zhu, X., and Khan, A.M. (2023) *BIM-based architectural analysis and optimization for Construction 4.0 (a comparison)*, *Research Gate*. Available at: https://www.researchgate.net/publication/367523278_BIM-based_architectural_analysis_and_optimization_for_construction_40_concept_a_comparison

20 Ruihua Ma, Ruijiang Ma, Enshen Long, Analysis of the rule of window-to-wall ratio on energy demand of residential buildings in different locations in China, Heliyon, Volume 9, Issue 1,2023,e12803, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2023.e12803

the average household electricity expense in Pakistan. Pakistan needs to utilize the savings potential for this aspect of building design and make it normal practice in the building sector. The government has already focused on this aspect which is shown by the building codes.

Areas of Improvement

1. Promote the Use of Simulation Tools: The study mentioned earlier involved the use of a simulation tool called COMFEN for analyzing the impacts of the window-to-wall ratio on heat gain. The use of such software should be normalized and architects and engineers should be proficient in using this kind of software, which can help them build and design better.

2. Awareness of the Public: The residential building WWR baseline is around the optimum WWR of 20-30%, but commercial buildings are not catering to this issue which shows that the architects and the local public still do not have any awareness of the importance and benefits of WWR on energy conservation and energy cost-saving of a building. The government can ensure awareness by doing media campaigns and providing technical and regulatory support for including WWR in building design.

3. Strengthen the implementation of Building Codes: Building codes do exist regarding window-to-wall ratio linking it with other factors. As Pakistan is a country with intense weather conditions, these building design features should be implemented on a priority basis to enhance energy efficiency and improve the overall health of the inhabitants of the buildings. The government can provide, capacity-building training to the public as well as labor, technical support, and guidance in design aspects, and certifications for building design related to WWR.

NATURE-BASED SOLUTIONS AND ARCHITECTURAL BEAUTY

Nature-based solutions incorporate biophilic elements in the building design to solve problems of increase in energy consumption, health and well-being, and emission reductions in a building. These solutions help sustainably tackle various issues, making the world more eco-friendly, resilient, and better for people, while also opening up opportunities for businesses and innovation such as for the production of green roofing systems and living walls inside buildings that reduce emissions and create a healthy environment.

ASSESSMENT OF BIOPHILIC DESIGN ELEMENTS

Biophilic design recognizes the inherent human need for nature together with sustainable and universal design strategies to create environments that truly enhance life. In urban and rural areas of Pakistan, residential buildings include certain biophilic elements such as gardens, lawns, pot plants, and in some cases, trees as well but commercial complexes do not focus that much on biophilic design elements.

In contrast, commercial buildings in Pakistan do not focus on introducing nature into the building design. Most commercial buildings and modern residential houses focus more on the inclusion of the latest technology and ignore the importance of biophilic design elements in buildings lacking the use of natural elements.

However, there are some initiatives such as the inauguration of Forest Town as a biophilic city by Green Woods Developments in Pakistan (Islamabad), whose concept was taken from a biophilic city named Tengah located in Singapore. It is a great step in addressing this issue aiming to transform urban living through eco-sustainability and biophilic principles with the mission to re-establish a profound connection between real estate and the natural world.[21]

Figure 10 - Forest town Concept (Tengah, Singapore)

These types of initiatives boost resilience by reducing the urban heat island effect, the risk of flooding, and improving the air quality, and enhancing residents' quality of life by maintaining good air quality. They also help in blending heritage with modern sustainable design, creating attractive spaces that showcase Pakistan's culture and attract both residents and tourists.

The importance of the introduction of biophilic elements can best be calculated by reviewing the cost savings through the inclusion of a green roofing system in a household. A study shows that the energy consumption for their base case was 169 kWh/m^2, while the energy consumption due to the application of green roofing on the entire roof surface came out to be 110 kWh/m^2 and the **energy savings were found to be 35%**,[22] which can save a lot in terms of energy cost.

Comparing this with Pakistan, the energy cost-saving potential of a green roofing system installed in a household in Pakistan can be calculated as follows:

21 Forest Town Reconnecting with Nature. https://foresttown.com.pk/what-is-biophilia-and-biophilic-design-an-in-depth-guide/

22 Mahmoud, A. S., Asif, M., Hassanain, M. A., Babsail, M. O., & Sanni-Anibire, M. O. (2017, March 29). *Energy and economic evaluation of green roofs for residential buildings in hot-humid climates*. MDPI. https://www.mdpi.com/2075-5309/7/2/30#:~:text=The%20case%20study%20showed%20that,of%2024%25%20to%2035%25.

Table 4 - Cost Savings due to green roofing system in an Average Household in Pakistan

Season	Average Household Electricity Cost (PKR)	Percentage Saving (%)	Cost after Green Roofing System (PKR)	Cost Savings (PKR)
Winter	3000	35	1950	1050
Summer	7000	35	4550	2450

Energy cost savings due to the installation of green roofing systems can be up to **2,450/- PKR per month for summers** and in **winters it can be up to 1,050/- PKR per month**. The installation cost of such systems can be high but the return on investment can cover the initial cost of the system, which shows that the installation of green roofs in a building is economically feasible.

However, biophilic elements such as green roofing systems are very uncommon practices in Pakistan the fact that NEECA National Energy Conservation Building Code 2023 mentions that 50% of horizontal exposed roof slabs of Buildings shall have a green roofing system, to manage water run-off from rooftops, to control internal temperatures within the top floors, and to reduce the energy consumption and carbon footprint of the building but these guidelines need to be implemented to get positive results. Pakistan lacks the implementation of building codes on the inclusion of biophilic design elements.

The analysis of nature-based solutions in a building design shows promising energy cost-saving potential such as **2,450/- PKR per month for summers** and **1,050/- PKR per month for winters**, and the government has also advised the inclusion of biophilic elements such as green roofing systems through the NEECA National Energy Conservation Building Code 2023 but there is a lack of implementation of buildings codes, and lack of awareness among the public, and professionals also.

Areas of Improvement

1. Promoting green features in building design: Commercial buildings in Pakistan mainly focus on the materials, windows, and other features for energy conservation but the introduction of several green and natural elements such as living walls, indoor plants, biophilic arts, lawns, gardens, and courtyards for a better indoor environment, natural cooling, energy conservation and reducing the carbon footprint is required. People who are living in apartments or do not have space for lawns can opt for living walls and small plant pots inside their buildings. This can be done by raising awareness among the public and educating them about the economic and health benefits of such systems.

2. Lack of Awareness of the Architects and Labor: The labor and design experts lack awareness and knowledge on the benefits of incorporating biophilic elements into the building design. Biophilic elements ensure well-being, emissions reduction, and good aesthetics in a building. Relevant individuals must be educated and trained to implement these features in the buildings. Relevant professionals should be given training on the inclusion of nature-based solutions in building design in Pakistan.

3. Review and Implementation of Building Codes: NEECA Energy Conservation Building Code 2023 contains a whole segment on the introduction of green roofing systems into the building design to reduce the overall carbon footprint as well as to improve the energy efficiency of the building. Building codes should also be reviewed to contain guidelines on the use of natural elements in courtyards, lawns, gardens, etc. to improve the carbon footprint and energy ever further. To ensure implementation, the Government can provide, training programs to professionals as well as to youth, certifications, and campaigns on the health benefits and emissions reduction caused by to inclusion of biophilic elements.

ENERGY PERFORMANCE AND USE IN ARCHITECTURE

At present, buildings account for roughly 40% of the total energy consumed globally and the construction sector consumes 50% of the total energy of Pakistan.[23] If this energy consumption trend persists while factoring in the expected increase in population, and with limited new sources of fossil fuels, all the natural resources of Pakistan could be exhausted within a short period. The field of construction holds a significant potential of 30% for lessening its environmental footprint by integrating energy-efficient technologies into the planning, building, and maintenance of both new and existing structures.[24]

INTEGRATION OF RENEWABLE ENERGY IN THE DESIGN

Renewable energy technology can play a vital role in optimizing energy efficiency and reducing the carbon footprint of the building. In Pakistan, Solar PV systems are becoming more common in practice in modern residential houses and large commercial complexes in urban areas. In contrast, houses in rural areas do not focus much on technology because of the high installation cost of the systems.

Commercial buildings in Pakistan focus a lot on the integration of renewable energy sources to fulfill their energy demands. One of the examples of a commercial building with solar energy integration is the Telenor 345 Head Office in Islamabad, whose 11% of the total energy consumption is fulfilled by solar energy. An array of PV Solar cells is installed on the roof of the building used to convert the solar energy into electrical energy. [25]

23 Baig, A. (2018). *Green Buildings as a Solution for Sustainable Housing: Role of Private Housing Schemes, Lahore, Pakistan*. Research Gate. https://www.researchgate.net/publication/327267222_Green_Buildings_as_solution_for_Sustainable_Housing_Role_of_Private_Housing_Schemes_Lahore_Pakistan

24 Sangeetha, Sripiya & Rishisha, (2017). A Review of Energy Efficiency in Building Construction. *Journal of Industrial Pollution Control.*

25 https://www.telenor.com.pk/static/2019/06/Sustainability-Report-2019-2020.pdf

Figure 11 - PV Solar Panels, Telenor 345 Head Office

The cost of solar systems is very high but the return on investment and payback period make it quite cost-effective, which can be seen from the study where the payback period for household solar systems of 5kW was calculated to be **3.98, 2.33, 3.99 & 6.78 years** in Sindh, Balochistan, Punjab and KPK, respectively. Other than that, there is a reduction in the carbon footprint of the building due to the solar systems as according to the Lawrence Berkeley National Laboratory, an acre of solar panels producing zero-emissions electricity saves between **121 to 138 metric tons, of carbon dioxide** per year. Solar systems are used commonly in Pakistan but there is still a lack of other renewable energy technology use in Pakistan.[26]

The integration of other types of renewable energy systems is also an option in a building design, a recent UK study part funded by the Carbon Trust study shows that small wind turbines can be used on top of high-rise buildings with an estimated potential **annual carbon dioxide savings to be in the range 0.75- 2.2 Mt CO_2 per year**.[27] The biomass energy system can also be integrated as explained in this example where biomass boilers were used for heating purposes. Biomass offers substantial advantages, including a significant reduction in CO2 emissions when compared to fossil fuels, resulting in emissions reductions of up to **95.25% for single-family units and 91.18% for multi-family units**. Additionally, the use of biomass enhances energy ratings, and leads to substantial economic savings, with **potential cost reductions of up to 70%** when compared to gasoil,[28] which shows the benefits of using other renewable energy sources in Pakistan.

26 Mahmoud, A. S., Asif, M., Hassanain, M. A., Babsail, M. O., & Sanni-Anibire, M. O. (2017, March 29). *Energy and economic evaluation of green roofs for residential buildings in hot-humid climates*. MDPI. https://www.mdpi.com/2075-5309/7/2/30#:~:text=The%20case%20study%20showed%20that,of%2024%25%20to%2035%25.

27 https://www.sciencedirect.com/science/article/abs/pii/S1471084606705455

28 Carpio, M., & Costa, M. (2013, August 6). *Impact of using biomass boilers on the energy rating and CO2 emissions of Iberian Peninsula residential buildings*. Energy and Buildings. https://www.sciencedirect.com/science/article/abs/pii/S0378778813004702

Figure 12 - The Swift Turbine[19]

Figure 13 - Biomass Boiler[29]

The government has already advised about the integration of solar systems as a renewable energy resource for buildings in the NEECA National Energy Conservation Code 2023, which contains a chapter on the design and integration of Renewable energy systems into buildings. However, the code only focuses on solar energy as a renewable source of energy for generating power. It states that the solar system should be designed at a minimum of 10 kW for 1000 units (kWh) for average monthly consumption. Average consumption must be based on the technical analysis of the solar capacity potential of the building by considering the surrounding buildings and their shades on the concerned building. Other options such as wind energy and biomass energy can also be used as renewable energy sources for buildings but there are no guidelines for them in the building codes of Pakistan.

The analysis of renewable energy sources in building design shows the importance of integrating renewable energy systems such as solar systems, wind energy systems, and biomass boilers in buildings. Buildings in Pakistan have shown the integration of solar systems in their design to fulfill their energy needs. Other renewable energy sources can also be used in the building design to utilize their cost-saving and emissions-reduction potential.

Areas of Improvement

1. Diversification of Renewable Sources: There are various renewable energy sources used in different parts of the world but in Pakistan, the focus is mainly on solar energy. There's a need to explore and integrate a wider variety, especially in regions with high potential for wind energy, and biomass energy. The best practices from other countries can be utilized in this regard.

2. Awareness and Education among Builders and Public: There should be increased awareness and education about the benefits of renewable energy technologies among builders, architects, and the general public because if people are not aware of the benefits of using renewable energy and the negative impacts of using fossil fuel-based energy, they will not be willing to integrating this type of technology into buildings. The government should provide capacity-building training to the relevant professionals and general public, certifications should be introduced, and technical and regulatory support should also be ensured.

29 https://finbra.co.uk/renewables/biomass-boilers/

3. Financial Incentives: Government incentives and subsidies should be expanded to make renewable energy systems more affordable and attractive for building owners as renewable energy technology comes with high installation costs, which can put a lot of financial pressure on the homeowner. Incentives such as tax reductions, low-interest loans, and grants can be provided to homeowners to integrate renewable energy systems in their buildings.

4. Implementation and improvement of Building Codes: Building codes do exist on renewable energy but they focus only on solar energy integration. Also, the building codes are not followed with regularity in Pakistan, which needs to be addressed. Federal and provincial governments can play a crucial role by assuring the implementation of regulations \to promote the widespread use of renewable energy sources in buildings.

COST ANALYSIS OF BUILDING DESIGN FEATURES

The existing building selected for the case study is the double-story Automotive Centre of the University of Engineering and Technology Lahore (UET Lahore). It has a total area of 6903.6 m2 (74312.16 ft2).[30]

Figure 14 - Automotive Centre of University of Engineering and Technology Lahore

Further details of the building have been provided in Table 5.

Table 5 - Detailed Information on Building

Parameter	Value/Description
Building Orientation	Long Axis facing North-South
Number of *stories*	2
Total Area	6903.6 m2
Total Volume	10666 m3

30 Ahsan, Muhammad Mubashir, Muhammad Zulqernain, Hassaan Ahmad, Basit Ali Wajid, Saqib Shahzad, and Muzamil Hussain. "Reducing the operational energy consumption in buildings by passive cooling techniques using building information modelling tools." International Journal of Renewable Energy Research (IJRER) 9, no. 1 (2019): 343-353.

Total Area of Exposed Walls	640 m2
Total Windows Area	368.6 m2
Window-to-Wall Ratio	0.58
Floor Height	9.15 m (30 ft.)
Indoor Design Temp.	260 C
Operating Schedule	8 am- 8 pm (260 Days)
Occupancies	250 persons
Infiltration Rate	0.25 EACH
Lighting Level	400 lux
Appliances (Computer)	80 (Heat Output 160W/PC)

BASELINE DESIGN

The materials under consideration include brick plaster for wall finishes, single-glazed aluminum frames for windows, brick tiles for roofing, exterior paving for the flooring, and hollow-core plywood for the doors.

Applying Retrofitting Techniques

The following techniques are applied to convert a normal/ conventional building into a green one.

- Replacement of Single Glazed Windows with Double Glazed
- Modification of Window-to-Wall Ratio
- Application of Insulation
    - Selection of the most efficient insulation
    - Selection of optimum insulation thickness
- Application of Energy-Efficient Lighting

Assuming that all the previously single-glazed windows in the building are replaced with brown-tinted double-glazed windows while maintaining other parameters unchanged. This is considered because double-glazed windows' benefits reduce energy consumption and enhance indoor comfort levels. It's worth noting that substantial energy savings can be achieved through envelope insulation and energy-efficient lighting.

Additionally, the notably large WWR is optimized to fall within the range of 0.33 to 0.37, by the recommendations set forth by the Building Energy Codes of Pakistan. Furthermore, the existing 40W fluorescent tube lights are assumed to be replaced with 25W LED lights of the same luminous intensity.

REPLACEMENT OF SINGLE-GLAZED WINDOWS WITH DOUBLE-GLAZED

Replacement of single-glazed windows with brown-tinted double-glazed ones, while maintaining all other factors unchanged, can result in a 4.17% reduction in annual thermal loads.

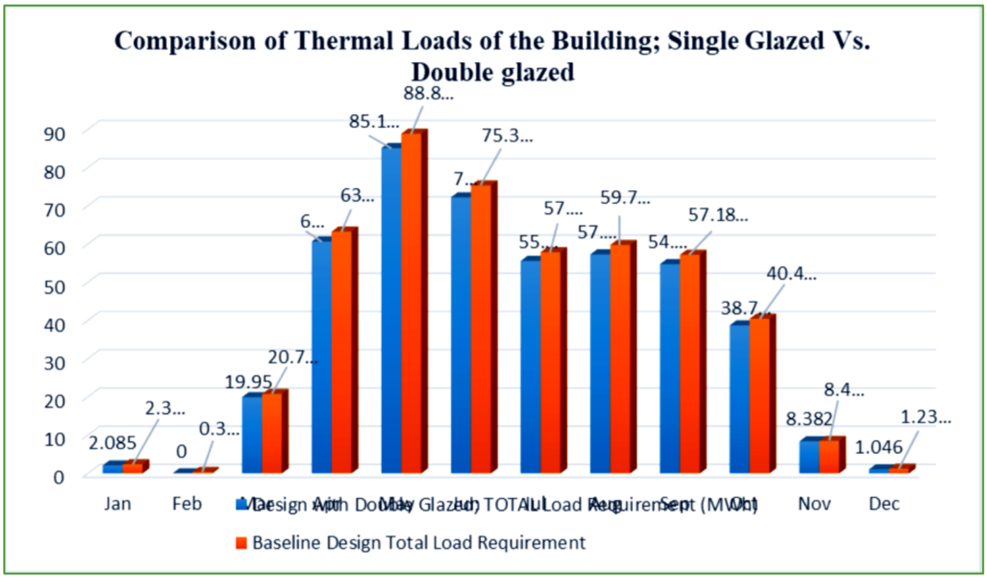

Figure 15 - Comparison of Thermal Loads for Single Glazed and Double Glazed Window

- Annual Load with Single Glazed Windows = 476.024 MWh
- Annual Load with Brown Tinted Double Glazed Windows = 456.150 MWh
- Load Saving = 4.1683%

MODIFICATION OF WINDOW-TO-WALL RATIO

In alignment with the guidelines stipulated by the Building Energy Codes of Pakistan, we have undertaken the reduction of the total window area from 368.6 m2 to 237 m2, accompanied by the implementation of shading measures on the remaining windows. This intervention has revealed an optimal window-to-wall ratio of 0.37, a configuration that minimizes thermal loads.

Subsequently, when comparing the total thermal loads post-optimization with the baseline design, our findings indicate a notable decrease in energy consumption, specifically amounting to 1.96%.

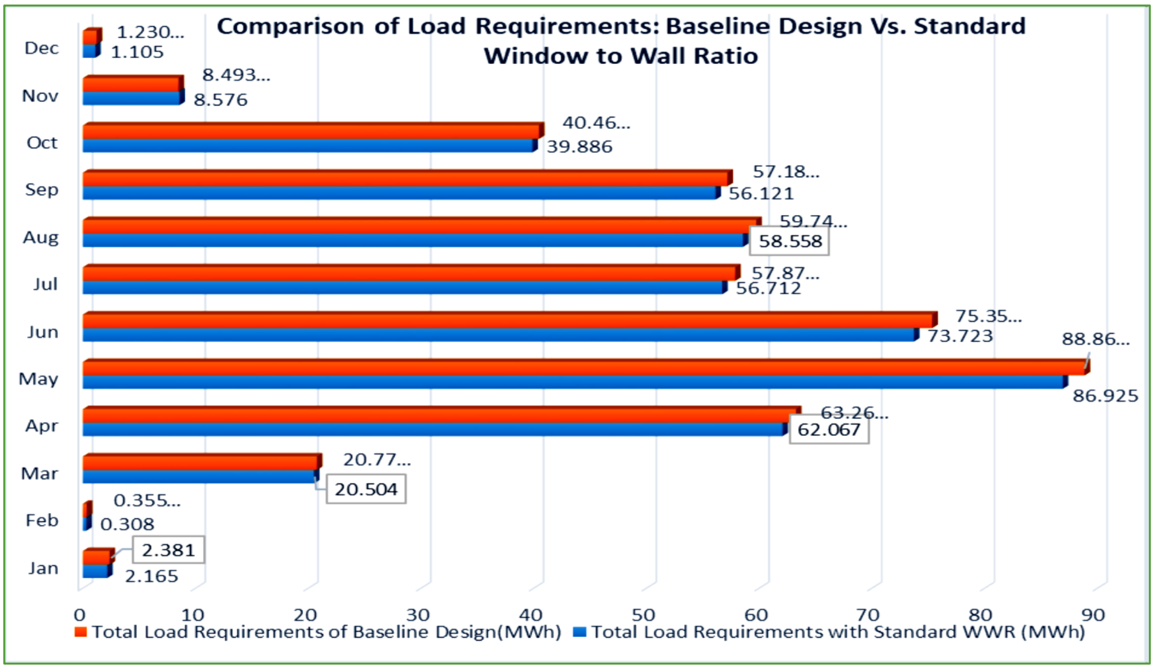

Figure 16 - Baseline Design (Actual) vs Standard Window-to-Wall Ratio for Green Building

- Annual Load with WWR of 0.58 (existing) = 476.024 MWh
- Annual Load with WWR of 0.37 (after retrofitting) = 466.651 MWh
- Load Saving = 1.962%

APPLICATION OF INSULATION

Roof Insulation

The roofing system has been insulated to minimize heat gains and reduce the cooling load of the building. To achieve this objective, the optimal insulating material has been selected, employing four types: cellulose, polystyrene, polyurethane foam, and rock wool. For the sake of comparison, a uniform insulation thickness of 2 inches has been applied on both the exterior and interior sides of the roof.

Findings indicate that polystyrene foam (high density) stands out as the most effective insulating material. However, it's important to note that due to its high flammability, it necessitates an additional layer of fireproof coating material. Typically, this involves the application of a fireproofing chemical known as Hexabromocyclododecane.

On the other hand, rock wool lacks additives that confer fire resistance, making it less suitable for use in extremely hot conditions, though it is inherently non-combustible whereas polyurethane foam employs CFC gas as a blowing agent, which contributes to ozone layer depletion.

Table 6. Insulations and their U values

Type of Insulation	U value (W/m2. K)	Density (kg/m3)	Specific Heat (J/kg. K)	Conductivity (W/m. K)

Cellulose	0.38	43	1,380	0.042
Polystyrene Foam	0.08	46	1,130	0.008
Polyurethane Foam	0.37	60	1,757	0.042
Rock Wool	0.31	200	710	0.034

Table 7. Total Load and Load Saving Using Each Insulation

Month	**Total Load (MWh)**			
	Cellulose	**Polystyrene Foam**	**Polyurethane Foam**	**Rock Wool**
Jan	0.36	0.309	0.358	0.343
Feb	0.003	0.959	0.003	0.002
Mar	15.29	15.011	15.288	15.21
Apr	45	43.91	44.8	44.551
May	62.17	60.884	62.17	61.81
Jun	52.8	51.714	52.8	52.497
Jul	42.275	41.524	42.275	42.065
Aug	44.301	43.557	44.301	44.093
Sep	42.075	41.347	42.075	41.871
Oct	29.953	29.442	29.953	29.809
Nov	7.933	7.837	7.933	7.906
Dec	0.361	0.367	0.361	0.122
Grand Total	342.317	336.861	342.317	340.279
Percentage Load Saving	28.132%	29.293%	28.132%	28.50%

Cellulosic insulation is the most eco-friendly insulating material, fire resistant and suitable thus it is finalized.

Optimizing Insulation Thickness

Analysis for optimizing insulation thickness has been conducted, involving the variation of insulation thickness from 0.25 inches to 8 inches in increments of 0.25 inches. It encompassed the evaluation of both annual load savings and the associated costs of insulating materials, with the final selection of the optimum thickness predicated upon cost considerations.

The graph given below (Figure 17) reveals a noteworthy surge in annual load savings, peaking at 10%, up to a thickness of 4 inches. Subsequently, the rate of increase in load savings diminishes significantly, causing a mere 0.6% increase up to 8 inches. This latter trend entails an increase in insulation costs. Consequently, 4 inches of thickness is selected as the optimized insulation thickness.

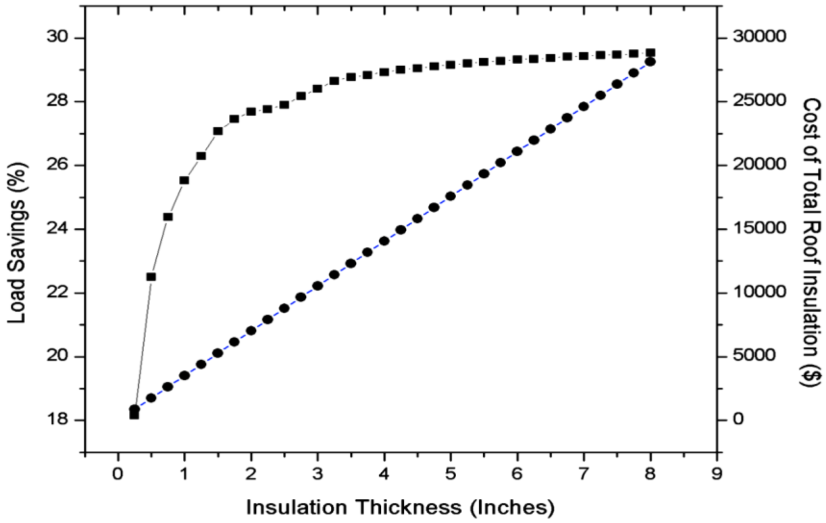

Figure 17 - Annual Load Saving and Insulation Cost Varying

APPLICATION OF ENERGY-EFFICIENT LIGHTING

The fluorescent tube lights used in the conventional building (40W) when replaced with 25W LED lamps to make it green (same luminous intensity), give a total 1.91% load saving.

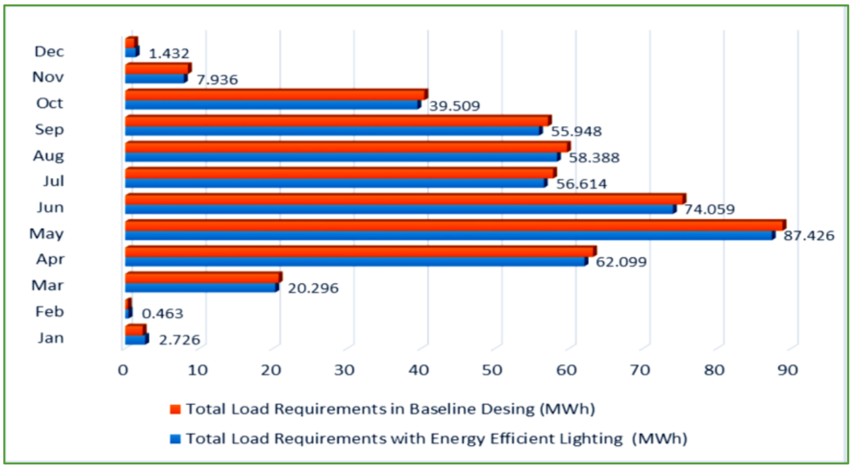

Figure 18. Thermal Loads by using energy-efficient lighting compared with the actual baseline design

OVERALL HEATING AND COOLING LOAD SAVINGS BY ALL TECHNIQUES

The effects of all the considered retrofits on the reduction of cooling and heating load requirements of the building are given below.

Table 8 - Overall Heating and Cooling Load Savings

Component	Composition After Retrofitting	Parameter	Actual Value	After Retrofitting
Walls	Ceramic Tiles 0.5", Cement Plaster 3/8", Brick Masonry 9", Paint Coat 1/4"	U value of Walls	1.882 W/m2. K	1.882 W/m2. K
Windows	Glass Standard 5/8", Air Gap 1", Glass Standard 5/8"	U value of Windows	6.065 W/m2. K	2 W/m2. K (Double Glazed)
Roof	Paint Coat 1/4", Cellulosic Insulation 4", Cement Plaster 3/8", Roof Tile 1", Cement Plaster 3/8", Cellulosic Insulation 4", Paint Coat 1/4"		4.921 W/m2. K	0.115 W/m2. K (Insulated)
Window to Wall ratio	Standard	WWR	0.58	0.37
Roof Insulation	Cellulosic Insulation	Insulating Material	No Insulation	4 Inch Cellulosic Insulation
Lights	L.E.D. Lights	Lights Power Rating	40 W	24 W

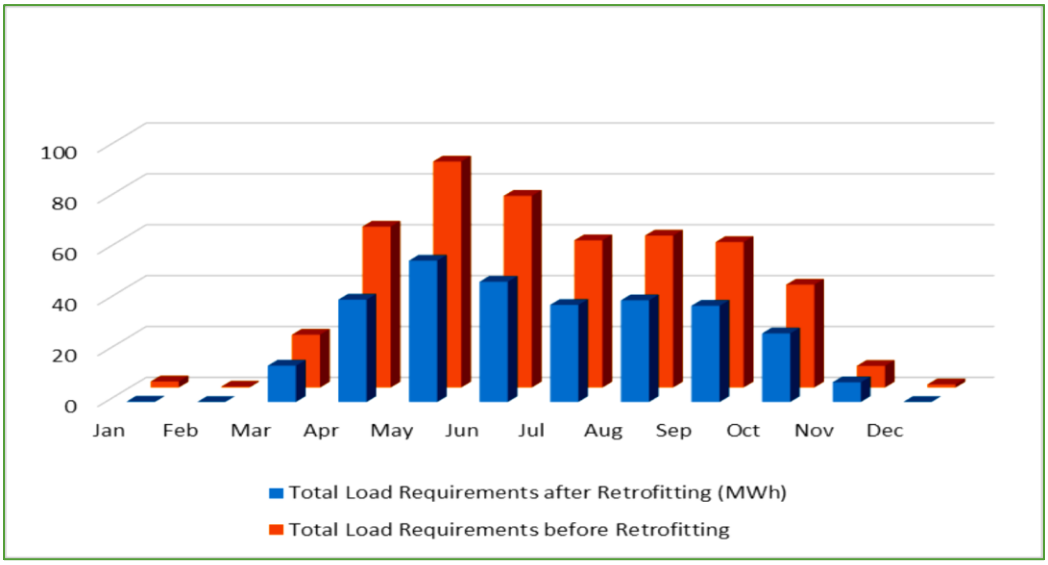

Figure 19. Load Requirements Before and After Retrofitting

OVERALL COST OF FEATURES

The cost of retrofitting techniques and electricity has been calculated and is given below. The table given below summarises the unit cost (Table 9).

Table 9. Uni Costs for Retrofitting and Electricity

Attribute	Unit Price ($)
Electricity price per kWh for commercial connections (inc' GST)	0.153
Cost of cellulose Insulation per square foot	0.408
Double glazed windows	5.1
23 W LED bulbs (Osaka Lightings)	3.1314
The price of a Cement bag of 50 kg	4.3044

The electricity cost is based on Lahore Electric Supply Company's general supply Tariff (2018) for commercial connections while the cost of cellulose insulation per square foot and that of windows per square foot are calculated with the help of quotes available online.

Note: The 2% inflation rate is adjusted to convert the cost in 2018 into 2023

Table 10. Costs and Savings of Green Building

Retrofitting Technique	Details of Cost	Unit Price ($)	Total Area to be retrofitted	The total cost of the	Annual Load	Energy Efficiency	Estimated Price of	Annual Electricity	Annual saving in

			(ft^2) or Number of Parts/pieces Required	technique ($)	Saving (kWh)		electricity per (kWh)	Saving (kWh)	terms of electricity ($)
Cellulosic Insulation		0.408	50209.3365	20485.409	167506	3	0.153	55835.33	8542.805
Double Glazed Windows		5.1	2551	13010.1	19841	3	0.153	6613.667	1011.891
Energy Efficient Lighting (Thermal Load Saving)		3.13140	120	375.768 0	9083	3	0.153	3027.667	463.2331
Energy Efficient Lighting (Direct Electricity Saving)							0.153	5920	905.76
Modification in Window to Wall Ratio and Shading	Bricks cost per piece	0.0816	5000	408	9339	3	0.153	3113	476.289
	50 kg Cement bag	4.3044	20	86.088					
	Estimated Labor cost			1958.4					

Total Cost/Saving				**36323.765**	205769			74509.67	**11399.98**

PAYBACK PERIOD

- Payback Period = Total cost of retrofitting for converting into green building / Total annual saving
- Payback Period = 36323.765/ 11399.98
- Payback Period = 3.18 years
- Payback Period = 3 years 2 months

The cost analysis of different design features used in a building shows that the overall initial cost of incorporating green design is high but the payback period is **3 years and 2 months**, which makes green architecture an economically feasible alternative.

DEMAND AND REFLECTION OF GREEN ARCHITECTURE

Limited adoption of environmentally friendly and energy-efficient building designs in Pakistan is primarily caused by low awareness of innovative building design features such as simulation software, window-to-wall ratio, nature-based solutions, and renewable energy systems among the general public and professionals, resulting in low demand for green buildings nationwide. Nevertheless, numerous advantages and opportunities make the adoption of green buildings environmentally friendly and cost-effective for Pakistan. The graphical representation of the analysis of the value chain and the challenges and opportunities that exist in the value chain of green building design in Pakistan are illustrated below in Figure 20.

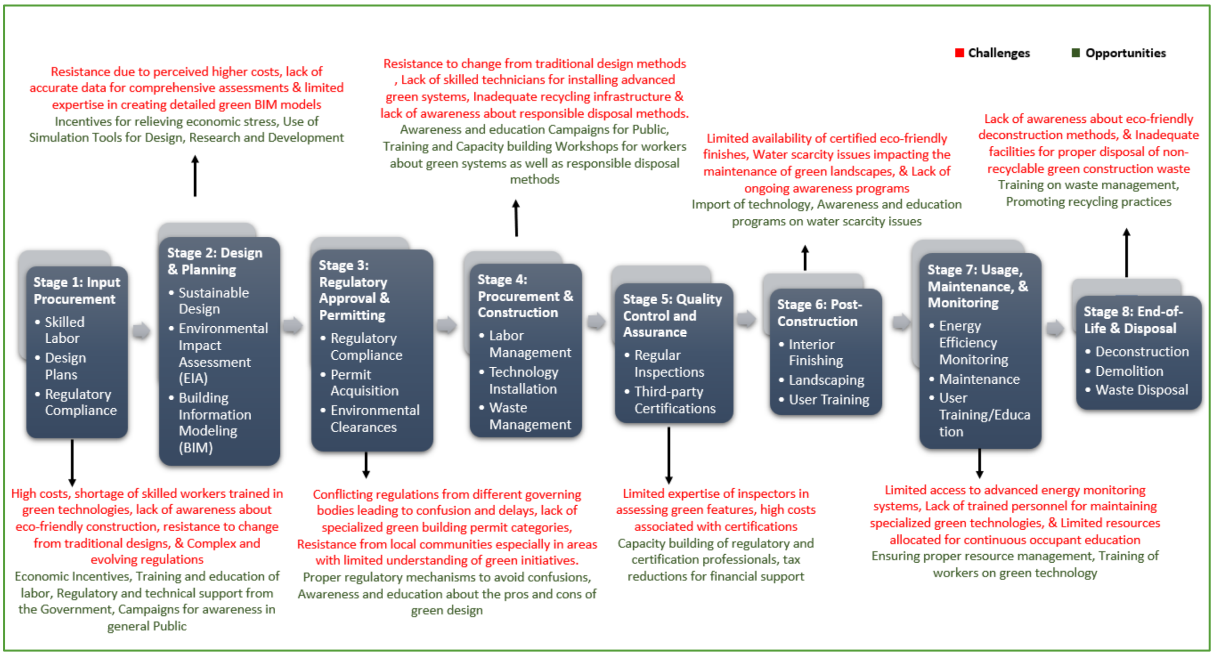

Figure 20 - Challenges and Opportunities in the Design Stages of green buildings in Pakistan Value chain

CHALLENGES IN IMPLEMENTING GREEN ARCHITECTURE

Pakistan is a developing country and lacks sustainable green building design in its construction sector. The reasons for the low demand for green architecture are as follows:

1. Lack of Awareness of Workforce and Public

In Pakistan, there is a significant lack of awareness among architects, owners, builders, and the general public about the benefits of green building practices. Many individuals may not fully understand the advantages of sustainable architecture or may be unaware of the available eco-friendly design options such as WWR, building orientation, biophilic design, or renewable energy integration. Also, many individuals have a strong preference for traditional practices and aesthetics, making it challenging to introduce new green building design concepts.

2. Weak Enforcement of Green building codes and policies

Building codes such as the PEC Building Code 2021 and the NEECA National Energy Conservation Code 2023 have detailed sections on guidelines about building design principles such as Orientation, WWR, Green roofing systems, and solar system integration but these guidelines are not being followed in the country. There are no proper mechanisms for ensuring the implementation of these building codes.

3. Economic Constraints

Economic considerations play a crucial role in the construction industry. Green building design features and technologies can be more expensive upfront compared to conventional options such as renewable energy, and green roofs. In a country like Pakistan, where cost-effectiveness is a significant concern, the higher initial costs of green design can deter potential investors.

4. Limited Access to Technology

The availability of green building design technologies such as wind energy systems, biomass boilers, Green roofing systems, and other biophilic design elements such as living walls are either limited or not present in most regions of Pakistan. The lack of easy access to these materials leads builders to opt for conventional alternatives.

5. Lack of Skilled Professionals

Pakistan faces a shortage of professionals with expertise in sustainable building design strategies. Without a sufficient number of architects, designers, and builders who understand green construction principles, the effective implementation of eco-friendly designs becomes difficult. The skilled professionals also lack knowledge on the use of simulation software such as Revit, COMFEN, and, other BIM modeling software, which has become mandatory to understand the applicable design strategies in a building.

STRENGTHS OF EXISTING BUILDING DESIGN IN PAKISTAN

The existing infrastructure in Pakistan has the following strengths which can be utilized and channeled for implementing green buildings and promoting green architecture in Pakistan.

1. Cultural Heritage and Architectural Diversity

Pakistan's rich cultural and architectural heritage, showcased by landmarks like the Badshahi Mosque and Lahore Fort, can serve as a wellspring of inspiration for contemporary building design. The nation's diverse regional influences have given rise to an array of architectural styles, offering architects a unique palette to create culturally resonant and visually captivating structures.

2. Craftsmanship and Resilient Practices

Pakistan possesses a longstanding heritage of proficient craftsmanship within the domain of architectural design. These skills can be strategically used to formulate building designs that are not only energy-efficient but also ecologically sustainable. Furthermore, traditional construction techniques prioritize resilience in the face of natural disasters, incorporating earthquake-resistant designs and locally sourced materials, which can be utilized during the use of green building design.

3. Adaptability and Community Engagement

Local builders and designers in Pakistan possess a remarkable ability to work with available resources while adapting designs to suit the local climate and cultural preferences, which can be beneficial for green architecture. In many cases, involving the community in building projects fosters a sense of ownership and ensures harmonious integration with the surroundings.

4. Geographical Advantages and Investment Opportunities

Situated at a crucial crossroads of trade routes, Pakistan's strategic geographical location holds immense potential for the development of modern infrastructure and transportation networks. This, in turn, can attract substantial domestic and foreign investment, fuelling the nation's growth.

5. Natural Integration and Technological Innovation

Pakistan's breathtaking natural landscapes provide a unique opportunity to seamlessly integrate nature into architectural designs, resulting in visually appealing and sustainable buildings. Moreover, as technology continues to advance, Pakistan has the chance to incorporate cutting-edge innovations in construction materials, renewable energy solutions, and smart building technologies into its architectural repertoire.

6. Educated Professionals in Modern Infrastructure

The country benefits from a pool of highly educated professionals in the fields of architecture, engineering, and related disciplines. These experts can be trained to shift towards sustainable design strategies.

OPPORTUNITIES IN ADOPTING GREEN ARCHITECTURE IN PAKISTAN

The following opportunities exist in Pakistan's construction sector which can be utilized by shifting toward sustainable and green architecture:

1. Addressing the Energy Shortage in a Nation Struggling with Frequent Power Outages

Pakistan faces a growing energy crisis, with buildings consuming about 50% of Pakistan's energy. To address this, Pakistan can embrace green building practices, like building orientation, optimal WWR, biophilic design elements, and green roofs, to reduce energy use and improve comfort, which can lead to energy cost savings of up to 30-40% on average. This aligns with sustainable development goals, such as Goal 7 (Affordable and Clean Energy), Goal 13 (Climate Action), and Goal 11 (Sustainable Cities and Communities). Given ample sunlight, integrating solar panels and other renewable energy sources into buildings can also promote renewable energy and reduce greenhouse gas emissions, further supporting sustainable development goals.

2. Cost Savings in Operations

Integrating sustainable building design practices into a building can offer a vast amount of energy cost-saving potential from different aspects such as **WWR saving up to 12-40% of energy cost**, **orientation saving up to 10-40% of energy cost, green roofing systems saving up to 35% of energy cost**, and renewable energy integration which can shift the whole energy consumption to renewable sources.[31,32] Given the circumstances, the potential for substantial growth offers a positive outlook for the green building industry to thrive, promising sustained rental income in the long run. This growth aligns with Goal 11 (Sustainable Cities and Communities) by ensuring accessible and sustainable housing for all.

3. Enhanced Quality of Life

Traditional building design methods in Pakistan often result in cramped living spaces with limited ventilation and poor indoor air quality for occupants. In contrast, green buildings prioritize fresh and healthy indoor air quality as a fundamental design element. Green buildings achieve improved indoor air quality by utilizing good orientation, nature-based solutions, and windows for heating and cooling. Consequently, green building practices offer a distinct advantage over conventional design techniques by creating a better and healthier lifestyle for occupants.

4. Promoting Sustainable Design Practices

Transitioning from these conventional design practices to energy-efficient alternatives holds the potential not only to conserve energy but also to curtail greenhouse gas emissions wind energy systems can save emissions up to **0.75- 2.2 Mt CO_2 per year** and the use of biomass boilers can save **95% to 99%** emissions as compared to fossil fuel-based energy.[33] Additionally, the use of sustainable

31 Ruihua Ma, Ruijiang Ma, Enshen Long, Analysis of the rule of window-to-wall ratio on energy demand of residential buildings in different locations in China, Heliyon, Volume 9, Issue 1,2023,e12803, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2023.e12803

32 Mahmoud, A. S., Asif, M., Hassanain, M. A., Babsail, M. O., & Sanni-Anibire, M. O. (2017, March 29). *Energy and economic evaluation of green roofs for residential buildings in hot-humid climates*. MDPI. https://www.mdpi.com/2075-5309/7/2/30#:~:text=The%20case%20study%20showed%20that,of%2024%25%20to%2035%25.

33 Emma Dayan, Wind energy in buildings: Power generation from wind in the urban environment - where it is needed most, Refocus, Volume 7, Issue 2, 2006, Pages 33-38, ISSN 1471-0846, https://doi.org/10.1016/S1471-0846(06)70545-5.

design practices aligns with Pakistan's goal of promoting responsible consumption and production, a crucial aspect of the Sustainable Development Goals (SDGs).

5. Utilizing the labor in an effective way

Pakistan boasts a substantial labor force of 68.75 million individuals.[34] This surplus of labor resources can lend support to the adoption of green building practices. Leveraging this circumstance presents an opening to promote the use of affordable labor for the integration of green building practices. This aligns with Goal 8 (Decent Work and Economic Growth) of the SDGs by creating employment opportunities.

6. Integration of Cultural design and modern technology

Building designs can be enhanced by integrating cultural elements and architectural heritage specific to Pakistan. This not only preserves cultural identity but also creates a sense of place in modern designs. By promoting a connection between modern architecture and cultural roots, sustainable design practices can contribute to Goal 11 (Sustainable Cities and Communities) by fostering community cohesion.

4. CONCLUSION AND WAY FORWARD

The building sectors such as the residential and commercial contribute most to the energy consumption in Pakistan. The analysis of building design in Pakistan shows a lack of sustainable design practices in the residential, commercial, and public sectors due to lack of awareness of architects and the public, lack of technology, and lack of implementation of building codes being the major reasons. The NEECA National Energy Conservation Code 2023 contains detailed guidelines on building orientation, WWR, green roofing systems, and renewable energy use. Integrating sustainable building design practices into a building can offer a substantial amount of energy cost-saving potential from different aspects such as WWR saving up to 12-40% of energy cost, orientation saving up to 10-40% of energy cost, green roofing systems saving up to 35% of energy cost, and renewable energy integration, which can shift the whole energy consumption to renewable sources. The cost analysis showed that by transitioning conventional buildings into green buildings from a design perspective payback can be received in about 3 years from energy savings. This demonstrates that embracing green building practices is cost-effective and environmentally friendly. There exist enormous strengths and opportunities in the construction sector that can be used to assist in the shift towards greener and sustainable design practices in Pakistan.

Looking ahead to the future of green buildings in Pakistan, there are both challenges and opportunities to consider. Pakistan faces energy shortages and environmental concerns. Green buildings emerge as a promising solution to address these issues and promote economic growth, social well-being, and ecological balance. By incorporating energy-efficient technologies and innovative design methods, green buildings can transform Pakistan's construction sector.

34 https://www.pbs.gov.pk/sites/default/files/labour_force/publications/lfs2020_21/LFS_2020-21_Report.pdf

However, there are some hurdles to adopting green building practices. These include concerns about high initial costs, economic realities, and the need to raise awareness among all stakeholders. It's important to review and improve the green building principles outlined in building codes and policies. In essence, a promising future awaits green buildings in Pakistan through collaboration, the sharing of knowledge, and an environment that supports green buildings and sustainable building design practices. By envisioning a future where buildings harmonize with nature and enhance people's well-being, Pakistan can pave the way for resilience, sustainability, and overall vitality.