Climate Smart Housing in Pakistan

Saleha Qureshi | Dr. Hina Aslam | Ubaid ur Rehman Zia
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Comments for improvement in this work can be communicated to Ms Saleha Qureshi at saleha@sdpi.org.
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<tr>
<td>CSH</td>
<td>Climate Smart Housing</td>
<td>GHGs</td>
<td>Greenhouse Gases</td>
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<td>MTOE</td>
<td>Million Tons of Oil Equivalent</td>
<td>SS Cs</td>
<td>Smart Sustainable Cities</td>
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<td>ICT</td>
<td>Information and Communications Technology</td>
<td>NZEB</td>
<td>Net Zero Energy Buildings</td>
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<td>AZEB</td>
<td>Affordable Zero Energy Buildings</td>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>NFIS</td>
<td>National Financial Inclusion Strategy</td>
<td>AAC</td>
<td>Autoclaved Aerated Concrete</td>
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<td>NADRA</td>
<td>National Database and Registration Authority</td>
<td>SBP</td>
<td>State Bank of Pakistan.</td>
</tr>
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<td>NPDHA</td>
<td>Naya Pakistan Housing Development Authority</td>
<td>NADRA</td>
<td>National Database and Registration Authority</td>
</tr>
<tr>
<td>PEC</td>
<td>Pakistan Engineering Council</td>
<td>GBC</td>
<td>Green Building Codes</td>
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<td>EBC</td>
<td>Energy Building Codes</td>
<td>GBGs</td>
<td>Green Banking Guidelines</td>
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<tr>
<td>EETs</td>
<td>Energy Efficient Technologies</td>
<td>ASHRAE</td>
<td>American Society of Heating, Refrigerating and Air-Conditioning Engineers</td>
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<tr>
<td>MPMG</td>
<td>Mera Pakistan Mera Ghar</td>
<td>EE</td>
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Executive Summary

In Pakistan, energy wastage and environmental degradation are coupled with increase in energy demand. Between 2015-20, the energy demand of the country had grown with an annual compound growth rate of 4.4%. Meanwhile, the total CO₂ emissions have also grown at a rate of 4.49% thus indicating a strong direct index between the two. While Pakistan's carbon footprints (2.18 t-CO₂/capita) are still below the global average, the disparity between livelihood conditions of developed and under-developed communities is significantly high. Consequently, Pakistan is ranked among the top 7 countries that are most severely impacted by the climate change. On average, Pakistan suffers an annual loss of $3.8 billion due to climate impacts. With the increase in global warming, these impacts are expected to exacerbate unless necessary measures are taken in terms of mitigation and adaptation.

As of 2020, almost 50 million people of Pakistan lacked access to reliable electricity while - approximately 50% population has no access to clean fuel and technologies. The inefficient use of resources not only adds to energy woes, but also leads to health hazards especially in the rural areas. Given this challenge coupled with growth in population, Pakistan has witnessed a growing urbanization thus causing a shortage of housing units. Against a demand of 31 million households, Pakistan has a total of 21 million households. Owing to this deficit of around 10 million units, a large population is living in slums and Katchi Abadis that are more severely impacted due to energy deficit and resulting in climate change.

Given the backdrop as highlighted above, the major challenge for Pakistan lies in decoupling its environmental profile from its energy consumption patterns. This would require a sustainable and resilient development through construction of climate smart houses and use of active and passive energy conservation techniques. This study, therefore, performs a socioeconomic and environmental analysis for climate smart housing in Pakistan while recommending a way forward through the use of active and passive energy conservation techniques. Given that a large portion of energy consumption from the residential sector is through cooling load, different passive construction techniques, i.e. Autoclaved Aerated Concrete (AAC) blocks, Interlocking bricks, and use of Insulation through rat traps are also analyzed to determine their energy and economic saving potential in the local context.

Based on an extensive desk review around status quo of climate smart housing in Pakistan, this study highlights that while the interventions for energy efficiency and resilient urban development were indicated in many federal and provincial policies, their ground level implementation and compliance has been the major challenge. The major development came in the form of Building Energy Codes (introduced in 1990 and revised later) by Pakistan Engineering Council that provide the minimum required standards for various building components based on their overall heat transfer coefficient values (U). Later, in 2008, these codes were revised, but still the implementation remained a major challenge. In 2011, the energy provisions for building sector were developed and finally in 2013, these were incorporated into Pakistan Building Energy Codes. Later, many provisions such as seismic issues were incorporated into the codes. In 2016, parliament of Pakistan also approved a legislation for the enforcement of codes both at federal and provincial levels, but for most housing schemes, this remained a neglected area until 2021 where some progress was observed both on policy front as well as on-ground implementation.

The case study approach used in this working paper further indicates that if Pakistan in its building
construction techniques, significant socio-economic and environmental advantages can be achieved. The first intervention of replacing conventional bricks with AAC blocks indicates that the use of hollow bricks can lead to energy efficiency improvements of 25% as compared to clay bricks, while the use of AAC blocks can lead to energy efficiency improvements of 29% as compared to hollow and 35% as compared to clay bricks. For energy consumption, clay brick wall structure needs around 166.41 MJ/m² of energy while hollow block and AAC blocks required 126.40 MJ/m² and 69.26 MJ/m² respectively. Therefore, using AAC blocks even without any thermal insulation can save up to 60% of the energy. The greenhouse gas (GHG) emission analysis was conducted through embodied energy which indicated that CO₂ emissions from total embodied energy for clay bricks is around 63.05 CO₂-eq kg/m² while for hollow bricks and AAC blocks, this value is around 28.57 and 37.62 respectively.

Similar results were obtained through interlocking bricks where the use of interlocking bricks in a 2-story building can result in direct cost savings of around PKR 4,198,245 and construction cost savings of around PKR 2,380,520. This represents a 26% decrease as compared to traditional brick construction mechanism. To analyze the impact of using insulation materials, a comparative assessment indicates that annually 1669.48 kWh energy is required to achieve the comfort zone (18° – 26°) of a common household. Thermal load comparison of housing units with insulation shows a prominent difference in energy consumption. Both techniques consume the greatest amount of energy in July, but the energy consumption of the existing housing unit is 383.5 kWh and the energy consumed with rat-traps is 253 kWh, which is quite less than the former.

While each of these measures represent a better socio-economic case for construction in Pakistan, the major challenge lies in the market readiness (equipment, skills, technology, etc.) and fiscal mobility and willingness of people and industry to adopt this change. In current housing sector, there is a need to mobilize people to adopt climate friendly practices by facilitating them through green financing initiatives. These initiatives will play a critical role in triggering a financial flow towards these investments. Few such initiatives that can be implemented in Pakistan have been discussed in this study. Initially, the most common housing finance in Pakistan is the mortgage finance for getting ownership against a specific loan. However, as compared to other Asian countries, Pakistan has a very low mortgage to GDP ratio of 0.25. In 2020-21, the Government of Pakistan introduced a Government Markup Subsidy Scheme, also commonly known as “Mera Pakistan Mera Ghar (MPMG) Markup Subsidy Scheme”. This scheme can be availed in both conventional and Islamic banking mode where banks are providing financing for construction or purchase of the house at low financing rates. Along with these financing schemes that are already in place, the housing sector has a potential to utilize bonds and sukuks (Islamic Financial Certificate) that complies with Sharia.

Given that the public finance in Pakistan is limited, private expertise and international financing opportunities must be mobilized either through Public-Private Partnership (PPP) or mobilizing the multilaterals. Pakistan’s national policies and programmes that integrate CC considerations and remove barriers for facilitation of large-scale private financing in climate-smart adaptation and mitigation infrastructure, including PPP legislation and policies, must be put in place.

**Keywords:** Energy Efficiency; Energy Conservation; Climate Smart Housing; Green Financing; Energy Planning.
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1. Introduction

1.1. Background

Climate change is one of the most critical existential threats to the vulnerable populations across the world. The informal settlements and low-income communities are at the highest possible risk due to climate-induced disasters, inefficient use of energy resources and lack of awareness for energy conservation patterns (Ali et al. 2021). The increasing frequency of climate-related disasters is also accompanied by a sharp rise in the world’s urban population. This means that more and more people are moving to climate-vulnerable cities and regions. In turn, their vulnerability and housing poverty undermines urban adaptation and resilience for all urban environments and citizens (Makkonen et al. 2015).

Since the beginning, communities have adopted different modes of living in the colonies, ranging from the houses made of mud and leaves to the strong concrete and polymers. As the development continues in the construction industry, it made the living conditions more convenient and stable (Wu et al. 2019). On the one hand where the industry had grown rapidly, on the other it has led to worsening the climate profile from due to greenhouse gas (GHG) emissions (Aslam, Nazir and Zia 2021). The impact of these emissions in the form of climate induced disasters is more eminent for the communities living in substandard houses. Global surveys have indicated that due to the lack of affordable, safe, and accessible houses, more than 1.2 billion people are living in these substandard houses (World Bank 2016a). An estimated 300 million new homes will be required by 2030 to bridge the global deficit, with most of this need concentrated in rapidly urbanizing Africa and Asia (World Bank 2016b).

The World Bank’s study on global housing has highlighted that by 2050, 68% of the global population will be urban, representing an increase of 2.5 billion people – with close to 90% of this increase being in Africa and Asia (United Nations 2018b). This urbanization will require a large construction in these geographies over the next few decades. It is estimated that 70% of the buildings that will exist in Africa and Asia in 2050 are yet to be built (United Nations 2018a). Considering that housing and construction contributes to 40% of global emissions, the biggest challenge yet to overcome is the construction of future cities that are both energy efficient and climate resilient (Carlin 2022).

Like other Asian countries, the residential sector is among Pakistan’s highest energy-consuming demand sectors (Aslam et al. 2020). In 2020, the building sector of Pakistan consumed approximately 14.5 MTOE of energy with a total share of around 28%. Resultantly, it contributed to around 21 million tons of CO2-eq emissions. Under the business as usual scenario, this value is expected to be approximately 37 million tons by 2040, representing an annual increase of around 3.01% (Aslam et al. 2022).

Global Net Zero Targets

In 2020, the direct and indirect emissions from the building sector increased to around 9 Gt, depicting an annual growth of around 1% between 2010-20 (International Energy Agency [IEA] 2021). As per the recent report of International Energy Agency (2021), the trend of building sector emissions growth is depicted in Figure 1. This includes the drop in emissions resulting from the economic downturn caused by COVID-19.
Given the emissions rebound in 2021 due to increased energy demand, the sector is off-track to meet the targets of carbon neutrality by 2050. As per the targets of Net Zero, all new buildings and 20% of the existing buildings must go zero-carbon ready by 2030 (International Energy Agency [IEA] 2021).

Need for Resilient Development

Given this backdrop, the resilient development and necessary actions to meet the goals of Paris Agreement and the 2030 Agenda must lie at the heart of future thinking and investment. Quality affordable housing with secure tenure, clean water and sanitation is a catalyst for meeting the health and well-being needs of people living on low incomes. Building climate-smart housing sector assures that the construction of much-needed affordable homes will not result in negative future climate impact and instead boost climate resilience and foster social cohesion. Furthermore, delivering housing at scale will also catalyze macro-economic growth, job creation, and support financial inclusion in ‘building back better’.

The number of people living in informal settlements is expected to be more than doubled by 2050, i.e. three billion – the very same year when many countries aspire to meet their net-zero commitments (United Nations 2018a). Many more live in substandard houses, which are ill-equipped to deal with climate change and related disasters. A warmer climate will intensify events and seasons with implications for increased flooding and drought. This is already occurring globally and accompanied by a sharp rise in the world’s urban population, which means that more and more people are moving to climate-vulnerable cities and regions. Investment in climate-smart affordable housing is increasingly necessary to strengthen the long-term resilience of an increasing number of cities and their inhabitants.

Additionally, due to the events caused by climate change, informal and low-income homes are particularly at risk of climate-related disasters, as they are typically constructed by using poor materials and situated in vulnerable areas. Their vulnerability and housing poverty undermine urban adaptation and resilience for all urban environments and citizens. Cities can only demonstrate the capacity for resilience when this is rooted
in the successful provision of affordable housing to the least advantaged residents. By reducing property and livelihood loss and displacement, quality affordable homes can support communities to cope with disasters in times of disruption. If we are to substantially reduce the risk to occupiers in the event of climate-related hazards such as flooding, storms, heatwaves, and wildfires, it is essential at all levels of affordability that houses are designed and built appropriate, and risk-assessed locations.

1.2. Pakistan’s Building Sector Profile

In 2020, the building sector of Pakistan consumed approximately 14.5 MTOE of energy, with the larger share, i.e. 88% coming from the domestic sector (Hydrocarbon Development Institute of Pakistan (HDIP), 2020). Driven by a net increase in population, urbanization, and GNI/capita, the energy consumption from this sector has grown with an annual compound growth rate of 4.5% between 2015-20 (ibid). However, with the annual increase, the wasteful consumption of energy resources has increased proportionally. In the backdrop of missing regulatory and policy regulations, unawareness of energy-efficient appliances and passive conservation techniques, the wastage of energy in the building sector of Pakistan is almost three folds larger than that of the global scale (Aslam, Zia and Qureshi 2022). This further leads to environmental degradation and an economic burden on the consumer in the form of high fuel costs and electricity bills. In 2020, the residential sector alone contributed to around 18Mt of CO2 emissions. Figure 2 below indicates the energy consumption in both urban and rural residencies of Pakistan (Aslam et al, 2020).

Furthermore, due to the existing energy crisis, which has gotten significantly worse over the past 10 years, Pakistan’s social and economic development is at risk. The commodity producing sectors (industrial and agricultural) are now forced to use expensive self-generated electricity as a replacement due to extensive load-shedding. Therefore, the cost of goods and services has increased so tremendously that they fail to compete in local as well as international market. The existing energy infrastructure, which is largely dependent on imported and expensive fossil fuel, is a massive burden on fragile economy of the country. Therefore, where there is a need to decarbonize the energy sector, reduction in the annual energy demand through climate smart homes should be the priority.
1.3. An Overview of Climate Smart Housing

1.3.1. Climate Smart Cities

A smart sustainable city (SSC) is an innovative city that uses information and communication technologies (ICTs) and other methods to enhance the quality of life, efficiency of urban operation and services, and competitiveness, besides making it sure that it satisfies the needs of both current and future generations in terms of economic, social, and environmental factors. Smart mobility, smart residents, smart city administration, smart living conditions, and smart way of life are the essential components of a smart city.

Green Infrastructure (GI) plays a significant role in the urban environment in lowering energy requirements, providing ambient cooling effects, minimizing localized flooding, allowing the soil to absorb acidity, replenishing local groundwater supplies, and so forth. The description of smart environment includes smart energy, including renewables, ICT enabled energy grids, metering, pollution control and monitoring, renovation of buildings and amenities, green buildings, and green urban planning besides the efficient use and reuse of resources and resource substitution to further the aforementioned objectives. As a result, the creation of climate-smart cities is made possible by the use of green infrastructure design, environmental sustainability, and related ICT, with an important role also played by adaptation and limited but crucial mitigation strategies.

1.3.2. Essential Components of Climate Smart Housing

Most critical features of a sustainable/smart house are energy efficiency, low impact on environment, and low cost. Additionally, climate smart housing safeguards against the effect of climate change on the most vulnerable community and promotes water conservation along with other social benefits. Few social benefits of CSH are indicated in Figure 3.

![Figure 3: Social benefits of climate smart housing](Source: Figure designed by the authors through data retrieved from (Jia et al. 2021; Zairul 2021; Islam, Usman and Jamil, 2022))

Many of the house’s features are focused on enhancing productivity and assisting families in becoming more
self-sufficient and better equipped to deal with extreme weather disasters. Generally, a climate smart house has features as given in Figure 4.

![Energy Efficient Housing Components and Climate Smart Housing Components](image)

**Figure 4: Essential Components of a climate smart house**

### 1.4. Housing Practices in Global and National Context

#### 1.4.1. Global Passive Housing Concept

Passive housing concept and certifications are rapidly being adopted across the Europe where more than 25,000 passive homes were already built till 2010 (Passive House Institute (PHI), 2020). To further promote these standards, the passive house institute launched new initiatives in September 2020 such as OutPHit for faster, cheaper, and energy-efficient retrofits (OutPHit 2022). Affordable Zero Energy Buildings (AZEB) has also been launched for lifecycle cost reductions of new net zero energy buildings through optimization of the process. Passive Housing was also a part of Built2spec project for facilitation of best construction practices. This led to only 15-20% of total space heating load whereas the additional cost is only 10% of the total cost of buildings. Based on the design standards, these houses are designed in a way that cooling/heating demands are less than 15 kWh/m²a, and the consumption of energy does not go beyond peak heat load of 10 W/m² (Kylili, Illic and Fokaides 2017).

A typical passive house incorporates higher insulation levels, minimum thermal bridging, and maximum availability to use solar radiations for heating purpose. Although this is not mentioned in the standards, the larger number of passive houses have a timber frame. Passive houses are also equipped with better ventilation and heat recovery systems. Dalhstorm et al. (2012) performed lifecycle assessment on passive houses and indicated that a “Wood frame single-family residence building” that is designed on a passive housing concept can reduce cumulative energy demand by around 24%-38%. Lewandowska, Noskowski and Pajchrowski (2013) also performed life cycle assessment for these houses and indicated that energy demand of a passive house was 3.6 times lower than that of a conventional house.

Globally, many residential energy policies have been framed for presenting different energy saving programmes by signifying numerous potential areas for making interventions. Revised energy policies of China resulted in their energy saving potential from 14.65% to 24.9% thus providing a roadmap for the countries with similar demographics (Lin et al. 2015). Large share of energy can be saved after the implementation of national policies in the building sector by inspecting retrofits as per energy codes and
providing the construction industry with certified and labelled energy efficient building materials.

The energy efficient housing techniques are classified into active and passive techniques. The active techniques reduce energy consumption by increasing efficiency of various building services such as appliances for lighting, heating, ventilation, air conditioning and refrigeration. The passive techniques are used to improve the thermal performance of different building envelop components such as roofs, walls, floors, windows, etc. (An assessment of energy technologies and research opportunities 2015).

Both techniques have significance in attaining optimal level of living comfort. Human thermal comfort is associated with the number of different parameters such as indoor/outdoor air temperature, humidity level, air speed, etc. International standards such as ASHRAE 55 and EN 1525 are used to evaluate these levels. A building envelop separates inside of the building from hot or cold outside and it determines the amount of energy required for the building operation as it minimizes or eliminates the use of mechanical heating and cooling systems. By insulating different components of the building, envelop can reduce the use of mechanical heating and cooling systems up to 60% and 40% respectively (Sarkar and Bose 2016).

1.4.2. Existing practices in Pakistan’s housing sector

The key elements of Pakistan’s construction industry include clay bricks, hollow blocks, and red bricks that are employed as a construction material without any insulation. The construction materials are produced locally by different industrial units at both formal and informal levels, and their abundant production has made them easily available. As compared to other countries, the conservation patterns are still lacking as no appropriate practices are observed for cooling and heating in summers/winters, leakage, and orientation. Therefore, these conventional settings contribute to increased used of energy utilities and put significant burden on the living standards.

Based on the use of material, the housing sector is classified into three general classes i.e., pukka houses-built of substantial material such as stone, brick, cement, concrete, or timber; Katchi (or kuchha ["ramshackle"]) houses-constructed of less-durable material (e.g. mud, bamboo, reeds, or thatch); and semi-pukka houses, which are a mix between the two (International Union for Conservation of Nature [IUCN] 2015). Sand also plays a significant role in construction, and it is usually mixed with soil to make foundations of a building stronger. Moreover, mixture of water, sand and cement (called mortar) is used in the building of concrete materials (Zameen 2020b). On the energy efficiency front, there is a rapid increase in the use of some energy efficient appliances, however, since the larger share of population resides in rural residencies, the technology penetration index is below the global average. According to National Energy Efficiency and Conservation Authority, a major potential to improve intensity is household appliances as identified in Table 1.
Table 1: Energy Saving Potential of different residential appliances in Pakistan (National Energy Efficiency and Conservation Authority (NEECA), 2020)

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Sector</th>
<th>Energy Saving Potential</th>
<th>Key Interventions Required</th>
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<tbody>
<tr>
<td>1</td>
<td>Building Envelopes</td>
<td>40%</td>
<td>Insulated Walls, Energy Efficient Construction</td>
</tr>
<tr>
<td>2</td>
<td>Lighting</td>
<td>29%</td>
<td>Transition to LEDs, Rural Technology Support such as Solar powered off-grid lights, Skylight Illumination</td>
</tr>
<tr>
<td>3</td>
<td>Fluorescent Ballasts</td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Air Conditioners</td>
<td>18%</td>
<td>Consumption Patterns, Behavioral Change, Passive Heating/Cooling Techniques</td>
</tr>
<tr>
<td>5</td>
<td>Heaters</td>
<td>17%</td>
<td>Passive Heating Techniques, Solar Water Heating</td>
</tr>
<tr>
<td>6</td>
<td>Fans</td>
<td>55%</td>
<td>Passive Cooling Techniques</td>
</tr>
</tbody>
</table>

1.5. Scope and Objectives

The built environment, ecosystem services, energy consumption patterns, and climate change have a significant impact on urban infrastructure and services. In marginalized and low-income areas that lack access to basic amenities, the scale of these impacts would undoubtedly increase the already existing socio-economic tensions as well as environmental risk drivers. In response to urbanization, improved energy availability, increased ownership, and the use of energy-intensive equipment, building demand and building area are expanding quickly. Owing to the interconnection of current development imperatives, catastrophic risk reduction, and climate adaptation, a comprehensive climate change adaptation strategy and action plan are required. Given that a very limited literature exists on climate smart housing practices in Pakistan, this study aims to fill that gap through an extensive desk review of current status, and socio-economic analysis of passive conservation techniques through a case study approach.

Key objectives of the study include:

- Analyzing the status quo of Climate Smart Houses in Pakistan and the key measures (interventions) which can be built upon in the national context of Pakistan.
- Benchmarking & Comparative Assessment of Best Available Active and Passive Energy Conservation Techniques
- Analyzing the Socio-economic prospects of climate smart houses as compared to the traditional housing in Pakistan
- To explore the potential opportunities for financing of Climate Smart Housing.

Methodological Approach and Conceptual framework

The methodology of this study is focused on developing an inclusive strategy that can inform policy decisions for incorporating energy efficiency and energy conservation techniques in the housing sector of Pakistan. On policy front, the assessment framework is structured to identify the existing gaps in regulatory and fiscal reforms currently being implemented in Pakistan and then describe some of the key opportunities which
can be availed by the housing sector. On technical front, quantitative assessment has been carried out for analyzing the socio-economic prospects which energy efficiency and active/passive conservation techniques can provide. Both quantitative and qualitative data has been analyzed through the following tools:

**Desk Review:** An extensive desk review has been conducted to collect both quantitative and qualitative data, including:

- **Policy Analysis:** A review of existing policies for energy efficiency and conservation in Pakistan, building energy codes & standards, financing tools and housing schemes offered by the public and private sector, etc.
- **Technical Data Collection:** Data for conducting socio-economic analysis for the case studies which includes, construction costs, electricity tariffs, energy intensities, consumption patterns, etc.
- **Housing Practices:** Literature around current status of climate smart housing in Pakistan and benchmarking of best global practices.

**Stakeholder Consultations:** Along with desk review, the qualitative data has also been extracted from the following stakeholder consultations. Public-Private Dialogue on “Low Carbon Recovery to Support Green Financing in Pakistan”

- **Capacity Building Workshop and Training on the “Implementation of Green Financing Mechanisms in Pakistan”**

The conceptual framework around which the above-mentioned data analysis techniques and policy review are shaped is described in Figure 5.
2: Climate Smart Housing: Current Status and Socioeconomic Prospects

2.1. Status Quo of Pakistan’s Housing Sector

In Pakistan, the current 10 million housing shortfall is expected to increase beyond 13 million by 2025 (Zameen 2020a) as indicated in Figure 6. Housing shortage as a percentage of population is around 32%, which is significantly higher than our neighbouring countries with similar demographics, i.e. India (12%) and Bangladesh (18%) (ibid).

As opposed to this, the cost of making a house in Pakistan has clearly outpaced the average income values. In 2008, the cost of making a semi-pucca house in Pakistan was 60 times the daily wage of an unskilled worker (Pabani, 2021). Back in 1991, this value was only 8 times. As of today, the situation has further worsened, and statistics indicate that 60% of bottom earners are disproportionally suffering from the housing inflation. Almost half of urban population of Pakistan lives in either slumps or Katchi Abadi where they lack access to clean houses. Therefore, under these situations, cheap housing is a necessity for Pakistan.

According to Pakistan Bureau of Statistics, the average cost of an urban house/apartment is PKR 12 million while the average monthly income in urban areas is PKR 81,800 (Doctor 2022). This means an average person would need around 30 years to pay for it. Such a high ratio is one of the primary reasons that a government entity, i.e., House Building Finance Company (HBFC) Limited only provides loan for affordable housing to those that are making around PKR 70,000-100,000 per month.

The mortgage industry is characterized by low volume of finance. The mortgage to GDP ratio stands at 0.23% compared to the South Asian average of 3.4% (Bokhari 2021). The sector’s loan book comprises of a paltry 58,620 loans for a total outstanding amount of PKR 103 billion (Moini 2017), which is not a substantial increase from PKR 67 billion 10 years ago. For some context, just the incremental demand from low-income housing is more than a trillion rupees. In recognition of the need to increase housing finance in the country, housing is one of the seven key elements of Pakistan’s National Financial Inclusion Strategy (State Bank of Pakistan [SBP] 2015) with development and origination of new loan products assigned high priorities. The
government's flagship programme – Naya Pakistan Housing - aims to build five million low-income housing units in partnership with builders and construction companies.

2.2. Policy Landscape for Climate Resilient Development in Pakistan

Although policy support and incentives for the construction of climate smart housing in Pakistan has been very minute, the concept of resilient development was mentioned under most of Pakistan’s policy reforms on climate change. In 2011, Planning Commission of Pakistan initiated the idea of making creative cities through Framework for Economic Growth. The idea for a creative city under this framework was to encourage energy efficiency, foreign investments for infrastructure development, and the use of low-cost energy efficient construction mechanisms. Now, although FEG was never fully implemented, the document remained a benchmark for policy makers.

Vision 2025 (Ministry of Planning Development & Reform 2014) also proposed development of eco-friendly, creative, and sustainable cities. NCCP 2012 (Ministry of Climate Change 2012) also mentioned that there should be low-carbon emissions by human settlements via a proper management of fuel and energy. It clearly mentions that for mitigating the impact of climate change, municipal governments will introduce wastewater treatment plants, net-zero emission buildings, use of renewables in residential sector, and land use planning techniques.

For resilient urban infrastructure development, Asian Development Bank in collaboration with Oxfam and Omar Asghar Foundation launched an Urban Financing Partnership Resilient Community Development in Asia (ADB 2020b).

Under this project, Abbottabad and Sialkot were chosen and most vulnerable wards were identified for building resilience through stakeholder engagement from local community. Sindh Resilient Project (Group 2016) was also funded by the World Bank to build water resilience in the province and deal with floods and droughts. Flood embankments were built around many riverine canals and small dams for protecting community from flash flooding.

In 2006, the Punjab government established an Urban Sector Planning and Management Services Unit (Pvt.) Ltd. A team of around 400 experts was formed to give policy advice to both public and private sector organizations in the field of solid waste management, water sanitation, and municipal finance.

To further control water and air pollution in the cities, Pakistan has also put forwarded the sanitation policies at provincial and federal level. National Sanitation Policy of Pakistan (MoE, 2006) was a strategic framework for the federal government to mobilize sanitation coverage within the country. Its main goal was to divert the relevant waste from workplace and dwelling units through sanitary lines. Guidelines were provided to ensure safe transfer of solid, liquid, agricultural and industrial waste while ensuring that the sanitation programme is linked with city or regional planning. Further, this policy also described capacity building needs of stakeholders and increasing the awareness of sanitation and community mobilization. The policy further provides detailed guidelines for policy interventions in various sectors and subsectors.

Punjab Sanitation Policy 2015 (GoP, 2015) has a target of providing 100% access of sanitation services to
entire population of Pakistan by 2025. For a development plan across this policy, the provincial government was to allocate a budget with the help of private sector, international finance, and investments with lean loaning agencies. Programmatic approach for the policy had five key drivers, i.e. a community led sanitation, school-led sanitation, component sharing, disaster response, and sanitation marketing. Policy document further provides details on gender mainstreaming, quality monitoring, public toilet provisions, PPPs, sanitation models, and integration between water supply and sanitation services, capacity building, technological choices, and management of different kinds of waste. *Sindh Sanitation Policy 2017* (PHERD, 2017) had almost similar targets as those set in the Punjab sanitation policy where it aimed at supplying 100% population of the country with sanitation mechanism by 2025, and 70% of rural households by 2020. It had a key focus on aligning itself with goals and targets of SDGs, promoting the community-led approaches for strengthening the sanitary conditions.

Further, some regulatory and executive initiatives of Pakistan for integrating resilient development and energy efficiency in housing sector of Pakistan are as indicated in Figure 7

![Figure 7: Key Regulatory and Legislative Actions for Climate Smart Developments in Pakistan](Source: Figure designed by the authors through policy review)

### 2.3. Urban Challenges

Pakistan has a challenging urban environment. With a population of 20 million people, Karachi is one of the top 10 largest cities of the country with regular power outages, water shortages, transportation heatwaves, heat island effect, urban flooding, clogged drains, and poor solid waste management techniques. Lahore has also reportedly experienced the worst smog in recent years (Abdul and Yu 2020). Owing to poor air quality, Lahore is also ranked among the world’s most polluted cities. Despite these major issues and disaster recurrence, disaster management plans are lacking, particularly for those who are susceptible owing to lack of human resources and capacities. Climate change, uncontrolled urbanization, housing shortages, decreasing social capital, inadequate spatial planning, and ineffective building works by the government are some of the issues that the country faces (Satterthwaite et al. 2020).

State Bank of Pakistan (SBP) has estimated the urban housing shortage of 4.4 million in 2015. The five largest cities in Pakistan will have 78% of the total housing shortage by 2035 (Shaikh and Nabi 2017). The framework of economic growth and Vision 2025 has explicitly acknowledged the housing shortage due to horizontal
urban growth. For instance, around 0.2 million people lives in 1 km² in Dubai as compared to Pakistan where this number is 6,000 because of the horizontal urban growth.

Figure 8: A comparative assessment for city expansion plans of Dubai and Pakistan (Planning Commission)

Due to vertical expansion of buildings, Dubai can accommodate around 0.2 million/km². "Cost of expansion in Pakistan is 27 times the cost in Dubai"

Due to horizontal expansion of buildings, Pakistan accommodates only 6000/km².

Horizontal urban growth is one of the key reasons due to which Pakistan faces the shortage in number of housings. Over 20 million people do not have roof over their heads and 35% of our population lives below the extreme poverty line.

2.3.1. Urban Planning

Urban governance and management in Pakistan are carried out by the local governments. All the four provinces have their separate urban management and governance plans, but the country lacks urban policy institute (Ahmed and Haq 2021). The Framework for Economic Growth (FEG), prepared by the Pakistan Planning Commission, placed a fair amount of focus on encouraging urban creativity. In order to encourage mixed-use activities, energy efficiency, and vertical growth, and to privatize underutilized state-owned land and encourage foreign land developers to compete in the Pakistani real estate market, the concept of "creative cities" was developed. It also aimed to concentrate on research and development of low-cost, energy-efficient construction methods (Abdul and Yu, 2020).

FEG also clarified a number of complex regulations for advancing Pakistan's housing industry (Economics, 2020). For instance, it recommended updating the land registration process to use a centralized database, creating a housing database with the help of national organizations like the Federal Board of Revenue (FBR) and the National Database and Registration Authority (NADRA), registering property dealers, releasing unproductive state land, reducing the growth of slums, and promoting high-density, mixed-use urban development. FEG remained a benchmark for policymakers in the years that followed, despite never being put into practice.
The table above makes it very clear that Pakistani urban discourse mostly focuses on development. The attention should be paid on empowering communities, creating mass transit networks, addressing the housing issue, and saving valuable land by moving vertical. It does encourage innovative and environment-friendly cities to build energy efficiency.

### 2.3.2. Key Startups for Climate Smart Housing

**Modulus Tech Climate Smart Housing**

It is a startup that claims to make low-cost, energy-efficient flat-pack houses that have been used to help refugees, NGOs-built clinics in rural areas, and tourism projects. Each house is 16x16 square feet in size, with power and plumbing built into the panel walls. Each housing unit costs approximately $3,000 and has a 30-year lifespan (Reliefweb 2019). The houses are constructed with a steel frame and walls made up of recyclable materials, including fiber cement composites and wood plastic composites. Three individuals can put the houses together in three hours. The houses are energy efficient and cost-effective because of the use of glass wool insulation. The carbon footprint of a Modulus Tech house is predicted to be up to 52 times lower than that of standard concrete housing, and tests have shown that when the outside temperature was 50 degree Celsius, the temperature inside was roughly 35 degrees (ibid).
Aga Khan Agency

Aga Khan Agency for Habitat usually works with the communities to make their schools, hospitals, and homes safe and sustainable to withstand the natural hazards. This habitat not only provides support to the masons with safe construction practices but also safeguard people with floods, cyclones, and other natural hazards (Aga Khan Development Network [AKDN] 2020). In order to promote water and energy efficiency throughout the life of the building, its approaches were concentrated on the effective use of local, low-carbon materials and technologies. The foundation tries to encourage passive design strategies that rely on renewable energy from the environment to keep indoor spaces comfortable. To control the temperature and illumination levels in buildings, these strategies include insulation, shading, window size and orientation, and natural ventilation. In addition, low-carbon building materials include recycled steel, sustainable wood, rock, compressed earth, and low-carbon cement alternatives. Reusing as many resources as you can while cutting down on the expenses and emissions related to shipping new materials or getting rid of trash. The cool roof technology uses a highly reflective coating to reflect heat and reduce the need for cooling. To further reduce emissions from operations, the facility incorporates solar power, natural lighting, and ventilation, as well as rainwater harvesting and low flow plumbing fixtures.

2.3.3. Certified Green Buildings

As of now, Pakistan has six certified Green Energy Buildings i.e. Artistic Garment Industries (Pvt) Ltd, Karachi; Citibank Dolmen, Karachi; Coca-Cola Icecek AS, Multan Plant; British Council Library, Lahore; and Artistic Fabric and Garment Industries, Karachi. All these buildings are rated based on building energy performances, indoor air quality, energy efficiency and water efficiency (Landscape 2020). Reusing as many resources as you can while cutting down on the expenses and emissions relate to shipping new materials or getting rid of trash. The cool roof technology uses a highly reflective coating to reflect heat and reduce the need for cooling.

Additionally, there are also housing societies in Pakistan that claims to provide ecofriendly housing, having low impact on the environment and mainly designed and built by using technology and materials that reduce carbon footprints and require less consumption of energy.
In January 2020, Pakistan Tehreek Insaaf government had launched the Naya Pakistan Housing and Development Authority with the aim to build five million housing units in affordable schemes. They also claimed to build the ecofriendly infrastructure, but the project is still in planning phase (InsafPK 2020).

### 2.4. Global studies/best practices of CSH

Reall is pioneering in alternative materials, innovative green technologies, renewable energy solutions and disaster resilience. But, these must be implemented and delivered at scale without compromising affordability (Reall 2020). To do so will require dedicated action grounded in innovative new models and the crowding of dynamic partnerships. Few examples of best practices being observed across the countries are mentioned in Table 3.

### 2.5. Environmental and Social Benefits

Among key demand sectors, buildings have the highest emission reduction potential. As per the UNEP report, the GHG reduction potential of buildings by 2040 is around 84 Gt CO₂-eq through the use of energy efficient appliances, renewables, and fuel switching. The building sector has the largest potential for significantly reducing greenhouse gas emissions compared to other emitting sectors.

**Table 3: Global Practices for Climate Smart Housing**

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Country/Organization</th>
<th>Intervention/Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nepal &amp; Philippines</td>
<td>Compressed earth bricks and bamboo were successfully tested as cutting-edge, environment-friendly cement substitutes in the construction of affordable housing.</td>
</tr>
<tr>
<td>2</td>
<td>Kenya, Nepal, Zimbabwe</td>
<td>Pioneered cutting-edge sanitation and decentralized wastewater treatment systems (DEWATS) that serve more than 1200 low-income homes.</td>
</tr>
<tr>
<td>3</td>
<td>Mozambique</td>
<td>Piloted high-quality, reasonably priced housing for low-income residents of Beira that can weather the severe effects of Cyclone Idai in 2019, which destroyed 90% of the larger city.</td>
</tr>
<tr>
<td>4</td>
<td>Nepal</td>
<td>Facilitated the construction of more than 2,500 low-income households’ earthquake-resistant houses in Nepal. After the earthquake in 2015, several of the houses were still standing.</td>
</tr>
<tr>
<td>5</td>
<td>Australia</td>
<td>Introduced scheme for “Operational Zero Carbon Houses” under which no carbon footprints are generated during operational period. To offset grid emissions, these houses use onsite RE generation for its energy demand.</td>
</tr>
<tr>
<td>6</td>
<td>Reall</td>
<td>Introduced eco-friendly building techniques and technologies that are cutting edge and sustainable. These include a variety of more environmentally friendly cement substitutes, stabilized earth blocks, and prefabricated modular units. Reall has invested US$80 million in effective affordable housing development since 2000 with support from the governments of the UK and Sweden, housing more than 100,000 people and generating more than 80,000 new employments (REAll, 2021).</td>
</tr>
<tr>
<td>7</td>
<td>WorldFish</td>
<td>WorldFish and Practical Action collaborated to construct a model climate-smart home, located in Bangladesh's Shatkira neighborhood, close to the Sunderbans. The key feature of the house was its resistance to cyclones and flooding.</td>
</tr>
</tbody>
</table>
In the context of Pakistan, the environmental and social benefits of climate smart housing start with the concept of energy efficient building design and their readiness and willingness to adopt to the concept. Since there is no such data that could explain the information that would effectively encourage homebuyers to invest in sustainable housing (Zhou et al. 2016), therefore, it merits to investigate the buyers’ willingness to pay (WTP) for sustainable housing.

In Pakistan, there are several socio-economic factors that affect the consumer decision and WTP for the sustainable housing, i.e. low GDP and low paying capacity. The special characteristics that could affect the consumer sensitiveness towards willingness to pay are higher electricity prices (Barreiro-Hurle 2009). Thus, sustainable housing in the context of Pakistan is described to have passive architectural and engineering design aspects of energy efficiency, better indoor environmental quality, and reduced maintenance costs (Azeem et al. 2017).

While constructing and promoting sustainable housing is up to the real estate developers, homebuyers, being the last link of this supply chain, significantly influence this market through their willingness to pay (Zhang et al. 2016). Research also suggests that recognizing early buyers and their characteristics promote the adoption of sustainable products in a market (Winston 2010).

3: Socio-Economic Prospects of Energy Efficient Construction: A case study of AAC blocks, Interlocking bricks, and Rat-trap

3.1. Construction Materials

In the backdrop of a constantly growing energy demand of residential sector, a policy pathway is needed for transition towards energy efficient buildings. The key focus of this case study was to address the inefficiency of building structures and degraded comfort level in residential buildings of Pakistan. For this purpose, market available energy efficient materials are necessary to assess in terms of reduction in energy consumption and building lifecycle cost (An assessment of energy technologies and research opportunities 2015). Moreover, the use of thermal insulating materials and AAC blocks can lower the household energy demand particularly the space heating and space cooling (Kalhor and Emaminejad 2020).

The main focus of this case study is however on passive housing techniques. The passive techniques are used to improve the thermal performance of different building envelop components such as roofs, walls, floors, and windows, etc. Both techniques have significance in attaining optimum level of thermal comfort. Human thermal comfort is associated with number of different parameters such as indoor/outdoor air temperature, humidity level, air speed, metabolic activities, clothing, and physical activities. International standard such as ASHRAE 55 and EN 15251 are used to evaluate human thermal comfort. A building envelop separates inside of the building from hot or cold outside and it determines amount of energy required for a building operation. A thermally responsive building envelop is the need of hour, as it minimizes or eliminates the use of mechanical heating and cooling systems. Insulating different components of building envelop can reduce the heating and cooling demand of building up to 60% and 40% respectively.

The thermal performance of different building envelope components such as walls, roofs, and fenestrations can be improved by reducing their U-Values (overall heat transfer coefficient). Different worldwide practices
for treating external walls are thermal storage medium, wall insulations and reflective coatings. Thermal storage materials are usually effective in light weight building envelope. It is calculated using energy plus simulation that use of water as thermal storage medium inside the wall can reduce annual energy consumption by 8.6%. Thermal storage medium such as PCM (phase change materials) can also significantly improve the energy performance of building. In brick masonry walls, use of rat trap bond generates alternate layers of air cavities throughout the wall. These air cavities act as an insulating media thus preventing transfer of external heat inside the building during summer. Similarly, in winter, rat trap wall reduces the heating load by retaining internal heat of the building. Moreover, construction cost of such walls is 25% less than conventional Flemish bond masonry due to adequate saving of building materials (25% bricks and 40% cement).

Earlier, Pakistan used plain masonry for construction, but now a days, it has been converted into reinforced brick masonry as new and advance construction techniques. Reinforced brick masonry building codes was introduced in 1953. Uniform building codes (UBC), Building Codes of Pakistan (BCP), and different standards are used for masonry work in Pakistan. In reinforced brick masonry bricks, mortar and reinforce material are used in different regions where the quality and size of the brick are different. According to BCP, three types of masonry units are available in Pakistan. These include masonry unit of clay brick, masonry unit of concrete and masonry unit of other materials. All these units are constructed according to the UBC standards.

3.2. Scope and Methodological Approach

This section describes a case study conducted on energy and cost-effective construction with the aim to perform a comparative assessment of houses constructed through traditional materials (clay bricks, etc.) with houses constructed through the use of AAC blocks, rat-traps, and interlocking bricks. The study is supported by desk review and mathematical modeling of the data collected for both scenarios.

The design of geometry as well as climate conditions has been taken from two different studies conducted by University of Engineering and Technology, Taxila. Complete design details and the modeling mechanism can be referred through the research reports as mentioned above. This research, however, mainly focusses on the energy and economic assessment performed on the same buildings through the following key interventions:

1. Replacement of clay bricks with hollow and AAC blocks
2. Use of rat-traps
3. Replacement of clay bricks with interlocking bricks

Assessment framework for each component is shown in Table 4.

3.3. Comparative assessment of clay bricks with hollow & AAC blocks

The building designed for comparative assessment of the AAC blocks was a single-storey unit with a ground floor design as shown in the figure. Climate conditions of B-17 were used with component details (Annexure 1). The total heat demand of the building is calculated through the use of below-mentioned equations:

\[
\text{Heating Demand} = \text{Total Heat Losses} + \text{Total Heat Gains (THG)}
\]

\[
\text{THG} = \text{Free Heat Gains} \times \text{Utilization factor} = \text{Solar Heat Gain} + \text{Internal Heat Gain}
\]
3.3.1. Economic Assessment

While the detailed mathematical modeling is highlighted in the study, the final comparative energy efficiency of building through the use of different construction materials is shown in Table 5.

3.3.2. Energy and Environmental Assessment

Table indicates that for heating load management:
Use of hollow bricks can lead to energy efficiency improvements of 25% as compared to clay bricks.
Use of AAC blocks can lead to energy efficiency improvements of 29% as compared to hollow and 35% as compared to clay bricks.

Cooling load Analysis

1. Use of hollow bricks can lead to energy efficiency improvements of 40% as compared to clay bricks.
2. Use of AAC blocks can lead to energy efficiency improvements of 42% as compared to clay bricks and 47% as compared to hollow wall structures.

Total energy consumption

1. Clay brick wall structure needs 166.41 MJ/m² energy while hollow block and AAC block require 126.40 MJ/m² and 69.26 MJ/m² respectively. Therefore, using AAC blocks even without any thermal insulation can save up to 60% of the energy.

Total Energy Cost without any thermal insulation

1. Total energy cost of clay bricks in environment of Islamabad is around $1.81/m² while for hollow bricks and AAC blocks, this value is $1.377 and $0.684 respectively.
### Table 5: A comparative assessment of Energy Efficiency improvements through the use of Hollow blocks and AAC blocks

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Conv. Building</th>
<th>Efficient Building</th>
<th>% Energy Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal gains</td>
<td>2.4</td>
<td>2.4</td>
<td>100</td>
</tr>
<tr>
<td>Solar gains</td>
<td>1.1</td>
<td>1.1</td>
<td>109</td>
</tr>
<tr>
<td>Window losses</td>
<td>0.3</td>
<td>3.05</td>
<td>20</td>
</tr>
<tr>
<td>External wall losses</td>
<td>4.62</td>
<td>2.89</td>
<td>20</td>
</tr>
<tr>
<td>Ventilation losses</td>
<td>-0.4</td>
<td>6.3</td>
<td>100</td>
</tr>
<tr>
<td>Cooling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal heat loads</td>
<td>20</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Solar heat loads</td>
<td>36.3</td>
<td>22.2</td>
<td>30.4</td>
</tr>
<tr>
<td>Window losses</td>
<td>0.3</td>
<td>3.03</td>
<td>20</td>
</tr>
<tr>
<td>External wall losses</td>
<td>4.38</td>
<td>1.55</td>
<td>3.3</td>
</tr>
<tr>
<td>Ventilation losses</td>
<td>-0.4</td>
<td>6.3</td>
<td>20</td>
</tr>
</tbody>
</table>

*Note: All values are in kWh/m²a.*
**Total Embodied Energy**

1. Total embodied energy calculated for the clay bricks in Pakistan is 717 MJ/m$^2$ while it is 196.3 for hollow bricks and 338.3 for AAC blocks respectively.

**Environmental Emissions from Total Embodied Energy**

1. Environmental emissions from total embodied energy for clay bricks in Pakistan is around 63.05 CO$_2$-eq kg/m$^2$. For hollow bricks and AAC blocks, this value is around 28.57 and 37.62 respectively.

**3.4. Comparative Assessment of Interlocking Bricks with Conventional Bricks**

For interlocking bricks, a relative study between IHBS and conventional construction method for Reinforced Concrete Construction (RCC) was carried out. The geometry taken for analysis was a double storey building with approximate area of around 200 m$^2$. The building was designed through both construction methods, i.e., conventional bricks and EE interlocking bricks. For data and analysis on cost, construction time, required labour and overall statistics, the details were taken from the construction facility in Best Way Cement, near Heavy Mechanical Complex, Pakistan.

**3.4.1. Economic Assessment**

The results obtained from economic assessment of conventional and energy efficient construction have been shown in Table 6.

**Heat Transfer and Strength Properties**

1. Use of interlocking bricks in a double storey building can result in direct cost savings of around PKR 4,198,245 and construction cost savings of around PKR 2,380,520. This represents a 26% decrease as compared to traditional brick construction mechanism.
2. U-value is less than of interlocking bricks (>0.1) as compared to conventional bricks (<0.1), which shows they have more potential and feasible use for construction.
3. Heat transfer values of interlocking bricks is also less than conventional bricks, which means interlocking bricks are more feasible for construction purpose.
4. Strength of IEEB bricks is calculated to be 19.15 N/mm$^2$ which when compared to a similar sample of traditional bricks is 11% more.

**3.4.2. Use of Insulation Techniques (Rat-traps)**

For the use of rat-trap materials, this study assesses the cost of energy efficient house with the rat-trap bond used in construction. A comparative assessment of monthly electricity bills with and without the use of rat-trap bonds are shown in Figure 10.
Table 6: Economic assessment of construction through conventional and interlocking bricks

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Construction Activity</th>
<th>Cost in PKR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conventional Construction</td>
<td>7.50 million</td>
</tr>
<tr>
<td></td>
<td>- External Works – Earthwork, site clearance, mobilization, setting grid lines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Sub-structures – Excavation and fill, concreting, preparing formwork, layout on re-bars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Beams, columns, and slabs – Concreting, preparing formwork, layout on re-bars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Brickworks and plastering – Plaster on both sides, skin coating.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Transportation and machineries</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Roof trusses, windows, doors, plumbing and accessories</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Drainage and sewerage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Wiring, painting, and site clearance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Design and endorsement</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Interlocking Brick System</td>
<td>4.70 million</td>
</tr>
<tr>
<td></td>
<td>- External Works – Earthwork, site clearance, mobilization, setting grid lines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Sub-structures – Excavation and fill, concreting, preparing formwork, layout on re-bars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Ground Beams and slabs – Concreting, preparing formwork, layout on re-bars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Brickworks and mortaring – Lay the IHBS and filled with mortar.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Transportation and machineries</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Roof trusses, windows, doors, plumbing and accessories</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>- Wiring, painting, and site clearance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Design and endorsement</td>
<td></td>
</tr>
</tbody>
</table>

| 3      | Cost for Conventional Construction Brick                                              | 55            |
| 4      | Cost for Interlocking Brick                                                            | 27            |
| 5      | Saving in Labour                                                                      | 1.25 million  |
| 6      | Saving in Construction material                                                       | 2.10 million  |
| 7      | Total Direct Savings                                                                  | 3.35 million  |
| 8      | Total Direct and Indirect Savings                                                     | 26.60%        |

Figure 10: Electricity cost without rat-trap insulation
The above figures indicate that by replacing the conventional construction with the energy efficient materials (rat-trap), there is a significant decrease in the electricity bills in summers, which is usually below $30. The operational cost of the existing housing unit is greater than energy efficient housing. The monthly billing of EE house does not exceed from $38.20, and a straight cut of more than $9.55 per month can be achieved in the summer, as the billing of existing house is above $38.20 and building of EE house is below $28.65.

Electricity Savings

A comparative assessment for both components in the same climate zone indicates that annually 1669.48 kWh energy is required to achieve the comfort zone (18o – 26o). Thermal load comparison of housing units with insulation shows a prominent difference in energy consumption. Both techniques consume the greatest amount of energy in July but the energy consumption of the existing housing unit is 383.5 kWh and the energy consumed with rat-traps is 253 kWh, which is quite less than the former (Bukhari et al. 2021).

4: Housing Finance Opportunities

While the above sections have highlighted the socio-economic incentives of transitioning towards climate smart housing, the major challenge for the developing countries is the availability of finance to support this change. Instead of providing long-term and short-term socio-economic benefits, the capital cost of energy efficient construction as well as appliances used within the household have a higher upfront capital cost. This makes it financially unviable for low-income population groups. To overcome this challenge, financing support from both local and international sources has to be mobilized. This section identifies the key opportunities that currently exist for housing sector at national and global level.

4.1. Financing for Housing Sector

A large chunk of funding for the climate green finance comes from the developed countries that use private and public players such as the central bank, big corporations, and enterprises to allocate funds. Globally, the key milestone in climate finance was Copenhagen Accord (UNFCCC 2009) “Essential Beginning towards First Truly Global Agreement in which developed countries pledged $10 billion to developing countries until 2020, and the money was used to lessen the impact of climate change to the economy. According to UNEP, global initiatives in terms of climate finance reached to $2.5 trillion between 2010 and 2019. These finances come from banks, who have a big role in transferring finance and financial markets such as real estate that fix the
prices. Besides, there are financing mechanisms being globally deployed to assist in green investments such as market-based mechanisms, grants, loans, etc.

**Housing Mortgage**

The first instrument for house financing in Pakistan is the mortgage finance, which comes under a loan category to get the ownership of a house. Under this instrument, the individual transfers the ownership to the loaning facility under the condition that the ownership will return once the final loan payment and other mortgage terms are met. Pakistan has the lowest house mortgage finance to GDP ratio in South Asia with a value of only 0.25%. South Asia has an average value of 3.4%; (India (11%), Afghanistan (1%), Sri Lanka (8%), and Bangladesh (3%). This indicates that the mortgage use in Pakistan is very limited, however, in the past couple of years, the housing mortgage schemes have increased due to low GDP ratio. Figure indicates the current backlog and mortgage value of Pakistan in the past three years (Tola 2020).

![Figure 12: Housing Backlog in Pakistan (Tola 2020)](image)

**4.2. Existing financial opportunities for housing debt**

**4.2.1. NPDHA and SBP Policies**

Since July 2020, the State Bank of Pakistan has taken a number of actions to promote the supply of financing for the housing and construction sectors in order to achieve this objective of the Government of Pakistan. This facility was availed by low-income houses that has i) a maximum value to PKR 3 million; ii) has a covered area of up to 850 sq. ft., and iii) a loan size of up to PKR 2.7 million. The Government Markup Subsidy Scheme [63], also known as the Mera Pakistan Mera Ghar (MPMG) markup subsidy Scheme, was introduced by the Government of Pakistan in October 2020 to support these initiatives.

This programme, which is available in both conventional and Islamic modes, enables banks to offer very low financing rates for the construction and purchase of homes for low- to middle-income portions of the population. The following financing rates will be applied to the borrower under this plan:

- For the first five years, 3%.
- 250 bps for the remaining financing tenor
- plus 5% for the next five years' KIBOR
4.2.2. Support Schemes from Micro-Finance Banks

The government of Pakistan intends to greatly increase the number of housing units in the coming years and has already taken a number of steps in this direction, keeping in mind the need to improve the availability of adequate housing and the significant role that the construction sector plays in boosting economic activities. Individual Low-Cost Housing Loans are available from Microfinance Banks through the Government of Pakistan's Mark-up Subsidy Scheme. It offers a practical and cost-effective financing option for the purchase, building, and extension/expansion of homes and apartments under following conditions:

- Microfinance banks can loan qualifying borrowers up to Rs 2 million from commercial banks.
- Houses up to 125 square yards (5 marlas), with a maximum covered area of 850 square feet, are eligible for financing.
- Financing will be available for flats and apartments up to 850 square feet of covered space.
- The maximum price (Market Value) of a single housing unit at the time of approved financing shall not exceed Rs. 3.5 million in order to be eligible under MPMG.

![Figure 13: Financing Options for different category of houses under Pakistan Mark-up Subsidy Scheme](Source: Figure designed by the Authors through data retrieved from NRSP)

Islamic Financing

Based on the urge from larger population to use Shariah-compliant financing, the use of Islamic financing for house building has grown over the past years. The State Bank of Pakistan reported that 17 conventional banks and five Islamic banks operate in the country, both of which provide Shariah-compliant financial services.

Islamic financing methods can be utilized for building finance, and builders can receive similar financing either through reducing Musharka or Istisna. In Istisna, the bank will instruct a builder to create real estate for it before appointing that builder as its agent to sell that real estate to the end user. These forms of Islamic financing can help Pakistan's economy flourish while also benefiting the construction and real estate industries. Meezan Bank and Eden Builders signed an Islamic financing mandate for Rs 2 billion based on the Pakistani building industry's prospective expansion. The finance for a project in Naya Nazimabad was set up by HBL (Islamic banking) in which it choses to finance the land through Musharka.

Sukook Bonds

A Sukuk is an Islamic financial instrument that adheres to Shariah - the name for the Islamic code of law. Unlike bonds, which are indirect interest-bearing financial obligations, it entails a direct ownership interest in the asset. Bonds and Sukuk both offer payment streams to investors, however Sukuk income cannot be speculative in order to maintain Shariah compliance.
**Musharakah**

In Islamic finance, this is referred to as a joint business or partnership structure, where participants split an enterprise’s profits and losses. Musharakah permits the financier of a project or business to receive a return in the form of a percentage of the actual earnings in accordance with a predefined ratio because Islamic law (Sharia) forbids benefiting from interest in lending. Since a perpetual Musharakah has no set expiration date and lasts until the partners elect to dissolve it, it is frequently employed for long-term finance needs.

**4.3. Green Financing Mechanisms to support Resilient Development: Opportunities and Challenges**

Green finance is any financial activity that can affect the environmental outcome by channeling funds in sustainable practices like energy efficiency, renewable energy, waste management, boost biodiversity, pollution, GHG emission reduction, etc. It could also be a green lending, which is loading funds to sustainability projects or green equity investment which is buying shares in companies that help the environment.

Globally, the economies expect green financing to be the key achieving Paris Agreement goals. According to the International Finance Corporation (2019), green investment in the building sector is surging and expected to be one of the biggest global investment opportunities of the decade with an approximate value of $25 trillion by 2030. Many studies which have emphasized the environmental green bonds and CO2 emissions among the 10 high-income economies that encourage the green financing by having negative impacts on CO2 emissions. Some of the key features of the green financing are depicted in Fig 14.

![Figure 14: Market-based mechanisms for Green Financing (UNCTAD, 2014)](image_url)
Climate finance flows reportedly hit a record high of $608 billion in 2017, driven primarily by increases in renewable energy capacity in China, US, and India as well as increased public commitments to land use and energy efficiency, according to Climate Policy Initiative’s Updated view on the Global Landscape of Climate Finance 2019. The year 2018 saw an 11% decline to $540 billion. Based on the information now available, the Climate Policy Initiative’s initial projection indicates that 2019 climate financing flows will total $608–622 billion, which would represent a 6–8% rise above 2017–2018 averages. Development finance organizations such as Multilateral Development Banks (MDBs) and the International Development Finance Club (IDFC) are responsible for the growth.

4.3.1. Green Finance Market

In Pakistan, the implementation of green financing mechanisms is currently immature with few interventions coming from the central bank, i.e. the State Bank of Pakistan (SBP). The SBP introduced a framework for green banking guidelines to reduce the vulnerability of banks and Development Finance Institutions (DFIs). It further aimed to fulfil the responsibility of the environmental protection and transform the economy to resource efficiency and climate resilience. Later, International Finance Corporation (IFC) also signed an advisory agreement with SBP to support green banking.

4.3.2. De-risking of low carbon investment

Given the economic and political unrest in Pakistan, financial de-risking can be utilized to develop the interest of local and international investors. Under this mechanism, a large portion of the impact due to any causality is transferred to other parties such as banks. While the policy de-risking barriers and limitations in green projects are removed to reduce the likelihood of any such events but for de-risking the investments, it is essential to get smooth insurance and guarantees.

4.3.3. Green Bonds

Green bonds are globally the most commonly deployed green financing mechanism. It provides corporate banks and government to increase money. In typical bonds, an investor agrees to lend an issuer a particular amount of money for a specified time and in exchange, the investor receives periodic interest payments. The key thematic areas are indicated in Figure 15. These bonds also enable the loaning institutions for more stringent actions to improve environmental risk management and add environmental and social governance into credit-granting process.

The growing market trend and demand of the low carbon investment, Pakistan launched a $500 million Green Euro Bond. The bond was issued through the country’s state-owned Water and Power Development Authority (WAPDA) and is aimed to enhance the hydro power development of the country (Bloomberg 2021b).

Green bonds will increase potential to establish itself as a destination for foreign investments through ESG guidelines; issuing green bonds signals that Pakistan is looking for a low carbon future and green recovery. However, this would require a firm policy, regulatory support, and financial measures at the government end.
Transition and Brown Bonds

Transition bonds are comparatively a newer financing tool being adopted across the globe, especially in the wake of COVID-19. These bonds are different from the above-mentioned Green bonds that are targeted for green industries such as renewables. Transition bonds are more targeted towards “brown industries” with comparatively high GHG (Greenhouse Gases) emissions such as construction that are aiming to become greener or less brown (UNEP 2016). Given the urgent scale of need in Pakistan, transition bonds can spur a shift in such industries and increasing the green credit market.

Debt for Climate Nature Swaps bonds

Debt-for-climate and debt-for-nature swaps are policy instruments through which an existing debt contract is exchanged with another contract by discounting the original value. This could be achieved by refinancing at a lower market value, lowering the interest rate, or debt forgiveness. Debt for nature is comparatively not a very new financing mechanism (ADB 2020a). An agreement is used to reduce or cancel the debt servicing by the borrowing country in exchange for a commitment that the money saved through this agreement will only be invested in conservation or green projects.

Considering the financial stress of constantly increasing debt on Pakistan, limited fiscal space, and the off-tracked SDGs, debt swaps can support the country economically while at the same time supporting its climate objectives to restore it more sustainably through climate-friendly technologies and thus hold temperature rise to 1.5 oC.

4.3.4. Funding support from national and international banks and other green financing facilities

One strategy of the government must be to leverage resources to attract capital from various non-public sources, including private institutions and commercial finances like multiple sources of funding available globally. There is a large pool of large bilateral, multilateral financial institutions with green finance. Portfolio of projects and thematic focus can be on a range of different financing instruments such as Global Green Funds, Multilateral Green Funds, Sovereign Green Bonds, Bilateral Green Funds, and Private Green Investments.

Through grant support, ADB can help Pakistan through capacity building and knowledge sharing to develop proper mechanisms and develop facilities for policy inputs. This support can further be extended to design
bonds and other mechanisms, as previously mentioned. Additionally, loan funds can be designed to catalyze private capital.

For a green recovery, the role of private sector is critical, and many banks, through their lending schemes, are providing finance to the power sector in Pakistan. The World Bank, IMF, Chinese commercial and other banks invest in resources with Standard Operating Procedures (SOPs) diverted towards respecting the environment and climate change.

Over the past few years, many financing institutes and investors have been increasingly looking for sustainable investment opportunities. Global banks are shifting investments from fossil fuels and playing a significant role to de-risk the projects while making sustainable investments. A few key initiatives and trends are mentioned below:

Citi (an Investment banking company) vows to spend around $1 trillion in sustainable activities by 2030 (Surane 2021a).

There is a growing pool called “Global Capital” around the world from sovereign wealth fund, global pensions, and infrastructure funds looking for sustainable investments.

Oil and gas companies are looking for investments into renewables with a sizeable financial availability.

UN guiding principle on business and human rights,

The World Bank has also approved the RISE programme (Resilient Institution for Sustainable Economy programme). Under that, it is also implementing foundation reforms in the energy sector to transition to low carbon energy.

Further, there is a SAARC development fund. It has already given funding to Nepal and Bangladesh up to $15 million for single projects. They have financed projects for hydro, transmission lines and waste to energy in different countries. Pakistan can also avail such opportunity on very soft-term basis.

**IFC EDGE\(^2\) Certifications**

Integrating IFC EDGE certification to drive climate-smart decision-making in building portfolios: EDGE 16 supports the delivery of greener buildings by helping housing developers make better decisions earlier in the project process, quantifying improvements and creating an opportunity to certify these. For example, the EDGE tool helps developers identify cost-effective measures that can improve energy and water efficiency and reduce embodied energy in the materials used to construct buildings, contributing to emissions mitigation, and developing resilience. The belief that green certification is not possible for lower income housing in the global south is no longer valid. Instead, we must ensure that there is no trade-off between green and affordable if we are to meet the intersecting ambitions of the Paris Agreement and 2030 Agenda. Working with partners, Reall is committed to ensuring that 100% of its projects in affordable housing are EDGE-certified, demonstrating to the market that green buildings are possible and commercially viable at scale.

\(^1\)It is a regional body responsible for funding clean energy projects in the South Asian countries

\(^2\)International Finance Corporation (IFC) is a green building certification system focused on making existing building more efficient, EDGE is comprised of web-based software application.
5: Policy Recommendations

Current progress and major challenges highlighted in the study clearly identifies that Pakistan lags behind the other countries in order to overcome climate change impact. Though the policies were introduced by both the federal and provincial government facilities, they didn’t define the implementation and evaluation framework. The compliance with standards that have already been introduced is also lacking and the larger share of population is still living in substandard homes. This study highlights that from this point forward, the strategy that must be deployed must include three critical features as described below:

Critical features of Deployment Strategy for Energy Efficiency Houses

• Reduction in energy consumption through the use of energy efficiency technologies and changing the consumption behaviour and pattern of common households.
• Deploying energy conservation techniques to control the total embodied energy of the households, including construction materials and other on-site activities.
• Sustaining energy balance and reducing carbon footprints through efficient building design, building orientation, and use of off-grid generation sources.
• Critical features of Deployment Strategy for Climate Smart Houses.
• Pre-identification and site selection for reducing the likelihood of exposure to climate disasters such as floods, storms, and landslides.
• Use of proper design and construction strategies that reduce the potential damage from natural disasters.
• Ensuring that the flexibility of mechanical and structural systems is increased for future expansion.

Housing Authority

In Pakistan, the degree of control for implementing this strategy lies with provincial governments and mainly with the housing authorities. Their key responsibilities include the acquisition of lands, lending terms and contract management, design of societies and construction, and the process of home ownership and selection. An effective and mitigation plan that addresses the concerns of low-income households must go beyond this single selection to a portfolio of programmes and actions. On the one hand, this could bridge the federal, provincial and housing authorities to pull together their resources and technical knowledge to account for program requirements, while on the other, local building codes and land zoning may prohibit the types and siting of housing that the federal government may encourage.

National Resilient Development Programme

Federal and Provincial Units along with housing authorities should come up with a “National Resilient Development Programme” that inculcates the following:
• Develop relevant policies and regulations (such as incentives and reduced taxation on efficient appliances and insulation material) in order to facilitate the acceleration of adaptation of the existing regulations
• Review and update of EE regulations to ensure availing the funding, capacity, and resources for successful implementation
• Provision of required testing facilities and labs to verify & ensure the compliance with the issued regulations
• Capacity building and awareness raising campaigns for policy makers as well as communities about the importance of EE in building sector for climate change and energy security.
• Establishment of monitoring and surveillance process to ensure the successful implementation of the programmes.
• Development of energy databases to facilitate the processing of data at national & regional levels.
• Creation of regional technical platforms to exchange knowledge and successful experiences and provide the support and technical know-how for countries in the development of national programmes.

Attracting Green Capital

Based on the financing mechanisms described in this study, policymakers in Pakistan need to strengthen climate resilience in our ecosystems and push forward better synergy and convergence between climate, biodiversity, and health finance. Moving from relief to recovery requires a mindset that moves towards economic stimulus measures and reforms leading towards a long-term phase transaction. In this regard, there is a need to build upon the interventions as mentioned below:
• Policymakers (from both public and private sectors) need to rethink some of the unjust practices of expanding housing settlements in our cities and be mindful that to enable a sustainable growth trajectory, Pakistan needs to shift away from the linear solution model-where we solve one problem at time-to building models that address multiple solutions at a time. This would require immense public-private and community collaboration that provides a way toward economic recovery and improving our ESG conditions.
• Before Pakistan considers tapping into financing mechanisms and various funding resources, it is also important to align itself to see green frameworks with sector taxonomies worldwide. Orienting infrastructure investments to green and inclusive growth will also require company policy and regulating support.
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• United Nations Environment Programme (2016) Green Finance for Developing Countries: Need, concerns,


### Annexure 1: Building Components and their U-Values for AAC Blocks

<table>
<thead>
<tr>
<th>Building Component</th>
<th>Material</th>
<th>Thickness (mm)</th>
<th>Thermal Conductivity (W/mK)</th>
<th>U-Values (W/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External Wall (Type 1)</strong></td>
<td>External plaster</td>
<td>9.52</td>
<td>0.72</td>
<td>0.345</td>
</tr>
<tr>
<td></td>
<td>Clay brick</td>
<td>200</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Internal plaster</td>
<td>9.52</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polyurethane</td>
<td>50</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td><strong>External Wall (Type 2)</strong></td>
<td>External plaster</td>
<td>9.52</td>
<td>0.72</td>
<td>0.328</td>
</tr>
<tr>
<td></td>
<td>Hollow block</td>
<td>200</td>
<td>0.463</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Internal plaster</td>
<td>9.52</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polyurethane</td>
<td>50</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td><strong>External Wall (Type 3)</strong></td>
<td>External plaster</td>
<td>9.52</td>
<td>0.72</td>
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</tr>
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<td></td>
<td>AAC block</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Internal plaster</td>
<td>9.52</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polyurethane</td>
<td>50</td>
<td>0.021</td>
<td></td>
</tr>
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<td><strong>Partition Walls</strong></td>
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<td>0.72</td>
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<td>AAC block</td>
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<tr>
<td></td>
<td>Internal plaster</td>
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<td>0.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polyurethane</td>
<td>25</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td><strong>Roof</strong></td>
<td>Light weight concrete</td>
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<td></td>
<td>Jambolon</td>
<td>25</td>
<td>0.028</td>
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</tr>
<tr>
<td></td>
<td>RC Slab</td>
<td>125</td>
<td>1.046</td>
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</tr>
<tr>
<td></td>
<td>Cement Mortar</td>
<td>9.52</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td><strong>Ground Floor</strong></td>
<td>Ceramic tiles</td>
<td>12.2</td>
<td>0.309</td>
<td>1.349</td>
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<tr>
<td></td>
<td>Cement Mortar</td>
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<td></td>
<td>PCC</td>
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<td>Masonry Clay Brick</td>
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</tr>
<tr>
<td></td>
<td>Sand</td>
<td>100</td>
<td>1.711</td>
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<tr>
<td></td>
<td>Soil</td>
<td>200</td>
<td>0.837</td>
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</tr>
</tbody>
</table>
Annexure 2: ASHRAE standards for building

Although the building codes of Pakistan exist, it does not address the issue. Therefore, the NEECA, Planning and Development Division, was requested by the Environmental and Urban Affairs Division to develop the building codes as an addendum to the existing building codes of Pakistan. This code gives minimum performance standards for building windows and openings, heating, ventilating, and air-conditioning (HVAC) equipment and lighting. Though primarily based on American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards. Under the building standards, Pakistan divides into five climatic zones; standards have been provided for each zone.

<table>
<thead>
<tr>
<th>Building Components</th>
<th>ASHRAE Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roof/Ceiling</strong></td>
<td>The thermal Transmission value (Uo) for the gross area of the roof shall not exceed the given value in table 1.0</td>
</tr>
<tr>
<td><strong>Surface Separating Conditioned and Unconditioned spaces</strong></td>
<td>For surfaces that separate conditioned and unconditioned space, the Uo value shall not exceed the value given in table 1.0</td>
</tr>
<tr>
<td><strong>Walls</strong></td>
<td>The gross wall area above the grade shall have thermal, transmission value, Uo, not exceed the value in Table 1.0.</td>
</tr>
<tr>
<td><strong>Overall Thermal Transfer Value (OTTV) Requirements</strong></td>
<td>The cooling design for walls, floors and roof/ceiling is to be known as the overall Thermal Transfer Value (OTTV). It is aimed at achieving the design of a building envelope that adequately reduces heat design by both conduction and solar radiation to reduce the cooling load of the air conditioning system. a. heat conduction through opaque walls, roof/ceiling and floors. b. Heat conduction through windows and /or sky lights c. Solar radiation through windows and/or skylights</td>
</tr>
<tr>
<td><strong>Equivalent Temperature Difference</strong></td>
<td>Solar radiation on the building is a cyclic heat input. The outdoor air temperature also varies during the 24 hr period in a day. The Equivalent Temperature Difference (TDeg) concept shall be adopted so that the variable heat flow through the envelop may be calculated.</td>
</tr>
<tr>
<td><strong>Solar Factor</strong></td>
<td>The OTTV calculations requires a solar factor for glazing areas. The solar factor values for vertical surfaces for Pakistan should be taken as specified as 3.2</td>
</tr>
<tr>
<td><strong>Overall Thermal Transfer Value</strong></td>
<td>To energy conservation, the maximum permissible OTTV shall be form 29-32 for walls and 8.5 for roofs</td>
</tr>
<tr>
<td><strong>Air Infiltration</strong></td>
<td>The requirements shall apply only to those building components separating outdoor conditions from indoor conditions. All doors and openable sections of windows of air-conditioned buildings shall be weather-stripped. All fixed windows sections and other penetrations through the wall shall be caulked or otherwise sealed with a permanent material, for air-conditioned buildings.</td>
</tr>
</tbody>
</table>
Natural Ventilation

Natural ventilation should be designed for effective ventilation regardless of wind direction. There should be adequate ventilation when the wind does not come from the prevailing directions.

To obtain adequate air flow and velocity inside the buildings, the position of the opening relative to wind direction and the position and size of opening in adjacent or opposite walls should be carefully designed the minimum area of windows which must be openable for the purpose of natural ventilation shall be the following percentage of areas mentioned:
1. Residential (Bedrooms, Drawing rooms, Dining rooms, Kitchens) 50%
2. Water Closet, Toilet, Bathroom 100% Laundry, etc. Stairs, Utility 50%
3. Corridor, Stair etc. 50%
4. The total window area should be provided by at least two distinct windows which may be placed in adjacent or opposite walls.
5. Each window should not have more than 70 percent of the total aperture area. Wherever ceiling fans are used for cooling they should be of the blade diameter recommended in the Building Code of Pakistan.
6. Whole house fans may be used for the purpose of ventilation and cooling. Where these are provided, they should be sized to provide a minimum of 20 air changes per hour for the entire house.

Allowable Conductance and Resistance Values

<table>
<thead>
<tr>
<th>Elements</th>
<th>Symbol</th>
<th>Units</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>Uo</td>
<td>W/m²</td>
<td>2.67</td>
<td>2.56</td>
<td>2.22</td>
<td>2.5</td>
<td>2.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Btu/hr.ft²</td>
<td>0.47</td>
<td>0.45</td>
<td>0.39</td>
<td>0.44</td>
<td>0.39</td>
</tr>
<tr>
<td>Roof/Ceilings</td>
<td>Uo</td>
<td>W/m²</td>
<td>0.58</td>
<td>0.58</td>
<td>0.58</td>
<td>0.58</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Btu/hr.ft²</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Shaded Roofs &amp; Floors Exposed to</td>
<td>Uo</td>
<td>W/m²</td>
<td>1.16</td>
<td>1.16</td>
<td>1.16</td>
<td>1.16</td>
<td>1.16</td>
</tr>
<tr>
<td>weather</td>
<td></td>
<td>Btu/hr.ft²</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Floors Unheated spaces</td>
<td>Uo</td>
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Solar Factor for Walls and Roofs W/m² (Btu/h.ft²)

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