

Final Report for the 2008-2009 Student Travel Grant Award
Aga Khan Program for Islamic Architecture (AKPIA)

Study of Innovations in Building Energy Efficiency in Northern Pakistan

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Research Focus

Motivation

Despite the pristine beauty that captivates Northern Pakistan, which includes the Northern Areas and the high mountain ranges of the Hindu Kush, Karakoram and the Himalayas, the living conditions for the 1 million people that inhabit the land are harsh to say the least. The region is characterized by extreme climate, with temperatures as low as -20 C in the winter and is vulnerable to earthquakes.

There has also been a strong tradition of vernacular design, i.e. over the years the housing has evolved to suit the local environment and is built using local materials. However, the indigenous forms of construction are going out of practice in many rural areas. The transition in housing has been motivated by several factors. Firstly, building practices have been affected by the decrease in natural resources. The scarcity of wood for construction has resulted in people adapting their housing from using thick timber columns and beams to wooden poles. These changes have decreased the structural integrity of the housing. Secondly, with the increased access to materials such as cement, brick and steel in semi-urban and rural areas, there has also been an increase in the desirability for modern looking construction that has a better quality finish and is easier to maintain. Since, there has been difficulty in ensuring quality control in construction using such materials, deterioration in housing construction has happened simultaneously with modernization. Many homes built recently are unsuited for the climate conditions, as they rapidly cool in the winter and heat up in the summer. Thirdly, because of the increasing demand for more modern looking construction, the value for vernacular techniques has been undermined and there has been a decline in availability of labor with those skills.

The misery of people in some of the regions has been reflected by the level of poverty[1], which along with the factors mentioned above, has given rise to deteriorating housing conditions. Large sections of the population inhabit congested homes that are unbearably cold, non-ventilated and structurally unstable and are without basic facilities such as clean drinking water and safe disposal of liquid and solid wastes. There is also a higher incidence of acute respiratory infections amongst women and children, as they are exposed to high levels of indoor air pollutants as large quantities of biomass continue to be burnt indoors for heating and cooking.

[1] Studies conducted by the Aga Khan Development Network have shown that per capita income is close to $0.5/day, with unemployment and underemployment rates close to 70% because of a large sector of self-employment in many regions.

Yet today, there is even a greater need for improved understanding and extensive dissemination of information regarding innovations in housing energy efficiency. This is particularly because of the need to incorporate improved building practices for energy efficiency in reconstruction of homes and schools damaged by the earthquake in October 2005 and due to the ongoing conflict in the Northern Areas. Although transitional housing has been offered and some improvements in the seismic resistance of housing and schools have been prioritized- the sustainability of reconstruction efforts is constrained unless there is an effort to improve indoor living conditions alongside. If poor building energy efficiency is not addressed, millions would people would continue to be vulnerable. Not only would the increased consumption of fuel-wood and biomass to keep buildings barely warm in the winter result in increase in fuel expenditure ,time lost collecting fuel-wood but also increase vulnerability due to deforestation and climate change. Thus further adding to the poverty burden.

Having seen and interacted with people in the Northern Areas of Pakistan who were being affected by poor building energy efficiency and those working in the communities, I realized that there was an urgent need to make the cost of poor energy efficiency more obvious and the benefits through simple improvements more understandable and comparable. I had come in contact with the Aga Khan Planning and Building Services Pakistan (AKPBS,P) a few years ago and had heard of the significant efforts they had piloted since 1997 to improve housing products and building techniques. Over the past 10 years AKPBS,P installed over 8000 housing improvement products in households in the Northern Areas. Through past projects I was in touch with the staff from World Wide Fund for Nature (WWF). WWF had piloted initiatives to increase awareness about resource conservation, i.e. decreasing the amount of fuel-wood for heating and cooking, especially after the earthquake because of the threat of continued deforestation. On the other hand, I came in contact with the Central Asia Institute that were supporting community based education programs and construction of schools in remote areas of Northern Pakistan and saw the opportunity in improving design of schools. Thus I decided to spend part of the summer in 2008 learning more about the work that these organizations were doing.

Research questions

Given the existing initiatives I was interested firstly in learning more of what the current construction priorities and technologies were for improving energy efficiency and what preferences existed for fuels and end use devices for heating and cooking. Secondly, I wanted to develop a better understanding of the incentives and the barriers to the dissemination and adoption of the energy efficiency solutions. Beyond

these questions, I wanted to study on a basic level of how innovations in building energy efficiency had been adapted given the socio-economic and cultural aspect of housing and if there were any solutions that the community had developed despite the marginal economies and the constrained access to resources.

Audience

In order to answer some of these questions I decided to collaborate and design my fieldwork around projects of the three organizations mentioned previously. Some of the interests for collaboration in the study have been highlighted below:

Aga Khan Planning and Building Services, Pakistan (AKPBS,P)

- Get feedback on products from the community
- Highlight innovative adaptation of products
- Understand the replication strategy: demonstration model and entrepreneur training

World Wide Fund for Nature, Pakistan (WWF-Pakistan)

- Gather preliminary data on the fuel-efficient stove program
- Discuss educational component for energy efficiency as a part of the existing environmental awareness and conservation campaign

Central Asia Institute

- Identify opportunities to improve usability of schools through local innovations in insulation
- Assess the presence of local innovations and opportunities to promote entrepreneurship amongst the community

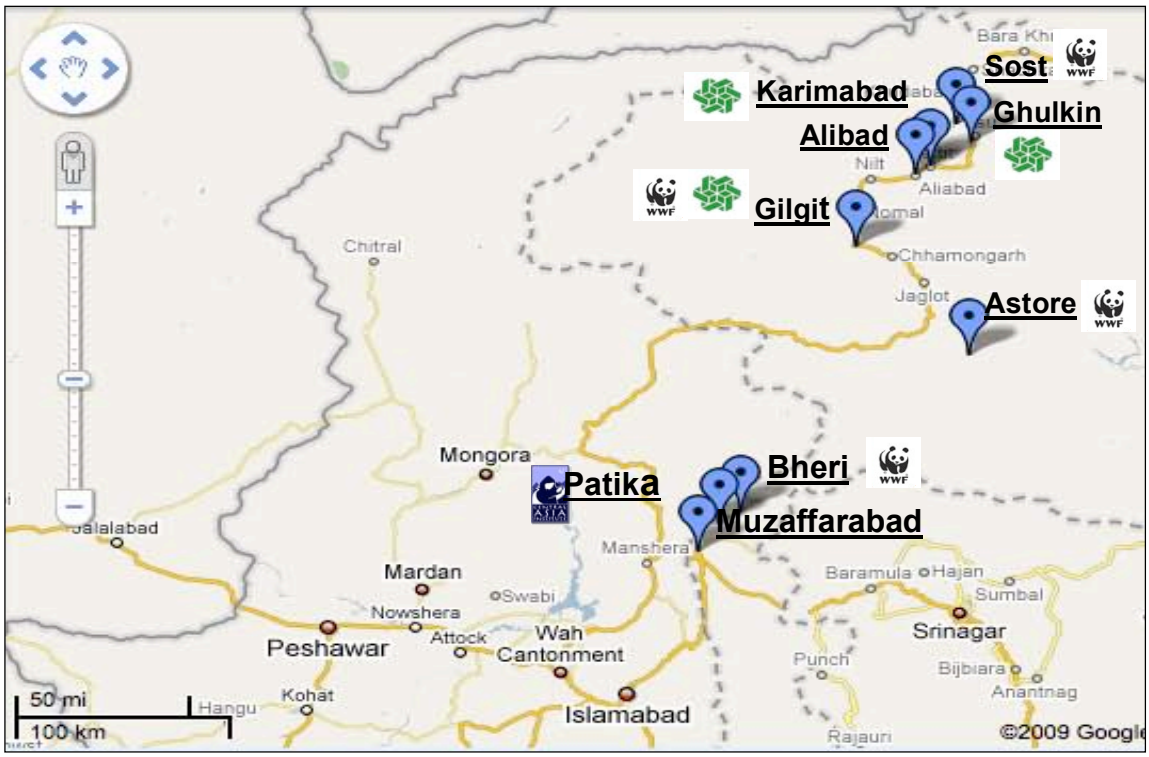
Method

For research purposes, I first conducted a rigorous review of existing literature ranging from studies on housing design, indoor air pollution and building practices in Northern Pakistan to proposals, internal assessment reports and educational materials and training manuals developed by of the some of the organizations.

I also spent four weeks in Northern Pakistan over the summer of 2008, surveying living conditions and conducting focus groups to collect the relevant data that would assist in my analysis and in answering some of the research questions. Current indoor conditions were assessed through measuring the difference between indoor and outdoor air temperatures and also observing the level of indoor smoke and surveying households on perception of thermal comfort. In order to better understand what the cooking and heating practices were, I conducted focus groups with

beneficiaries to understand what their needs and concerns were regarding the use of energy efficient housing products and further surveyed households to gather data on the fuel consumption patterns and use of energy efficient devices. An assessment of what the current construction priorities for energy efficiency were was made through observing what materials/ products were used for insulation if at all, if there were particular building techniques being promoted and if skill training was being provided for local manufacturing of housing improvement products. Lastly, to better understand the health implications associated with poor building energy efficiency I interviewed health workers on the incidence of respiratory problems and pneumonia within their community and inhabitants themselves regarding their medical expenditure and affect of poor thermal comfort on their productivity.

Plan



(In sequence of location visited)

- Gilgit: Meeting with staff at WWF Northern Areas head quarters and at the AKPBS,P office
- Astore: Visit to Read Foundation school and meeting with WWF staff involved with fuel efficient stove project in Astore
- Aliabad: Visit to Diamond Jubilee School
- Karimabad: Visit to Baltit Fort
- Sost: Meeting with WWF staff and participation in WWF activity for students on the World Environmental day

- Ghulkin: Visit to the Self-Help community school block and homes with traditional and modern construction
- Patika: Visit to CAI school
- Bheri: Visit to Kiran Public school, school built by Emergency Architects and households

Findings

This section presents the main findings regarding the conditions of the schools and homes that I visited and also discusses some of the innovations in building energy efficiency in context of the prevailing conditions. Towards the end of the section, a few ways to improve the delivery of the building energy efficiency products have been highlighted.

Schools

Most of the schools that I visited had to remain closed during the months of January and February because of the extreme cold. In some areas the schools would require heating for months from October to March. To heat the schools during the winter months, each student was required to bring a piece of wood which would be burnt in a stove called an 'angethi'. In most schools the angethi was attached to a metal chimney, which exhausted the smoke. In other schools, stones would be heated and then placed in the classrooms to radiate heat.

Out of the schools that I visited, the condition of two schools required immediate attention. One of them was the Kiran Public School in Bheri and the other was the Read Foundation school in Astore.

The top section of classrooms of the Kiran Public School had corrugated galvanized iron (CGI) sheets as the main roofing material and walls made from wooden planks, with huge gaps as windows. These classrooms were known for becoming unbearably cold in the winter as cold air would infiltrate very easily and there was no way to contain the heat within the room in the absence of insulation. The only strategy then used to protect the students against the cold was to make them wear layers of warm clothing, which would also get uncomfortable for them.

Right next to the Kiran Public School, was a school that was recently built by Emergency Architects, which was one of the organizations that had been involved in the reconstruction of schools after the earthquake in

October 2005. The school was designed with thick masonry walls and though CGI sheets were used for roofing, a false ceiling with insulation was also constructed to reduce the requirements for space heating and improve the comfort conditions for the students during the harsh winter months.

In the village of Bheri vis-à-vis improvements in energy efficiency of schools I found that the financial resources greatly determined whether the schools provided an adequate learning environment, especially during the winter season. Since Emergency Architects had been contracted by the government and had additional funds, energy efficiency was prioritized. However, for schools such as Kiran Public, due to the constraints in financial resources and also the absence of pro-activity on behalf of the school's administration- retrofitting the school building for improved energy efficiency was far from a priority.

On my visit to Astore, I visited one of the schools of the Read Foundation. The school building was constructed in 1986 and had three rooms where morning and afternoon classes were held for close to 120 male students and 50 female students. Along with the time off during the winter because of the cold weather, students were also given 20 days off during the month of August when it would become unbearably hot to hold classes indoors and even outdoors. During one of my conversations with the head master, I learnt that students who spent their time inside the small classrooms had a higher risk of heatstroke in the summer months, thus the administration tried to conduct as many of the classes outside in the shade to avoid such a situation. One innovative strategy I found was the use of plastic sheeting to cover windows to reduce the infiltration of cold air.

The remaining schools that I visited combined a number of innovative techniques to reduce the heating requirements for schools during the winter season, improve day-lighting in the classrooms and more

importantly use the resources from within the community to increase ownership of the schools themselves.

The Diamond Jubilee School that I visited in Nasirabad was built in 1986 and was a supported by the Aga Khan Educational Services Program. In addition to windows, each classroom had a skylight to improve day lighting. During most parts of the year the skylights were able to supplement the use of artificial lighting. However, regular maintenance was required in the winter months when it snowed to ensure that the skylights did not get covered with snow. The picture on the left shows the skylight at the top and also the a hole to which the chimney from the angethi would be attached to exhaust the smoke. Although concrete roof construction was used, the classrooms and hallways also had a wooden ceiling to improve the insulation and reduce requirements for space heating.

The self-help community school in Ghulkin was one of the most impressive schools that I saw in terms of designing for thermal insulation. Although the school was located in one of the windiest areas in the Hunza valley, through the design of insulated roofs and walls, the heating requirements were decreased to a minimum. The roof structure consisted of cement poured on the CGI sheet and with a layer of insulation on the interior, while for the wall structure masonry block followed by two layers of plaster on the inside was used. Also due to the high wind speed the roofs required proper anchoring. Not only were the CGI roofs held down by the layer of concrete on top but also clasped with steel posts to the wooden columns embedded in concrete.

The last school that I visited was a school in Pattika that the Central Asia Institute had helped set up. The school had been constructed to replace the one that had been reduced to rubble after the October 2005 earthquake. Pre-fabricated panels made from a GI sheet and expanded polystyrene insulation were the main components in the construction.

The lightweight construction, necessary for improving seismic resistance and the expediency with which the structure could be constructed were some of the main reasons behind the choice of this type of construction. Also, since many of the girls from the school had undergone the trauma from the earthquake and were scared to sit inside classrooms, an outdoor enclosure was built. Since the lack of ventilation in classrooms was one of the primary reasons behind overheating in the summer, the inclusion of outdoor enclosures also resulted in an increase in the usability of the school.

Each school discussed above, some of the improvements in energy efficiency were more deliberate, i.e. the use of insulation for walls and roof. However, innovations emerged as the as the community was involved in the design decision-making process and was given more ownership of the school. For example, the case of outdoor enclosures introduced a new way to design for improved thermal comfort in the summer while covering windows with cheap plastic sheeting decreased the heat loss during the winter season.

Housing design and products

Heavy earthen roof construction

Heavy earthen roofs were common in the traditional architecture, for the thermal mass offered by the thick mud roofs was able to maintain comfort conditions in the summer by keeping the rooms at a lower temperature and in the winter by providing insulation from the outside cold. However, there are constraints to promoting such construction since mud absorbs moisture and becomes heavier, thus increasing the seismic risk and can also result in the expansion of wooden beams due to contact with

moisture. Since roof collapse was the primary cause of death during the October 2005, the Government of Pakistan strongly urged against the construction of heavy earthen roofs- promoting light CGI roof construction instead. Since CGI roofs offered very poor insulation, many inhabitants preferred to live in their traditional mud and stone homes, while having the option of a seismically resistant shelter, which they built next to it.

This solution has not been optimal and has rather increased the risk of the population living in regions with high seismic activity. However, people have found a medium between the use of mud for increasing thermal mass of roofs and CGI for improving seismic resistance. The picture on the right is of a CGI roof with about 4 inches of mud placed on top of it. The CGI roof provides rigidity to the roof structure and decreases the contact of moisture of with the wooden beams supporting the roof, while the wooden beams on the edges prevent the mud from being washed away.

Wall insulation

BACIP has developed various techniques for wall insulation that can be applied to existing and new construction. The use of different materials such as straw, bags filled with sawdust and more recently polystyrene foam in cavity wall insulation has been promoted. The use of plywood and wire mesh with cement plaster is also common for wall insulation. The picture on the left is from a wall section of the demonstration house built by AKPBS in Gilgit.

The use of wooden paneling along the lower half section of the wall is a popular practice in some of the newer construction in the Hunza valley. Not only does the paneling have an aesthetic value but it is also purported to improve the comfort of the inhabitants who sit along the wall or sleep on the floor. Another technique used to decrease heat loss from the walls in the winter is to place cabinets and racks containing the bedding materials along the wall.

Some other innovative wall insulation techniques I heard of that were being used were rice husk for bale construction and insulation panels made from milk cartons.

Roof insulation/ ceiling

For some of the homes with light CGI roof construction, the inhabitants had either created false ceilings using plastic sheet or tarpaulin or from wooden paneling and had placed loose insulation on top. The picture on the left shows a house with a standard wooden ceiling. Roof insulation techniques have also been promoted by AKPBS,P in their regions of operation. The adjacent picture shows a ceiling fitted with saw dust insulation on the underside. Plastic sheets, wire mesh and GI wire were the main installation materials used. Also polythene foam insulation was promoted as another option for ceiling insulation.

Roof Hatch window

This product was developed under the BACIP program. The purpose of the roof hatch window was to cover the opening in the roof of traditional homes in the Northern Areas. While allowing in day-light it also provides the option to ventilate the room by keeping the hatch open or conserve heat by keeping the hatch closed. The picture on the opposite right shows the modern roof following the traditional design and fitted with the roof hatch window. While the picture below it shows different models of the roof hatch window on display outside the BACIP office in Gilgit.

Fuel-efficient stoves

Fuel-efficient stoves with chimneys for smoke extraction have been widely distributed in the Northern Areas of Pakistan to reduce the consumption of fuel-wood. Some of the households that I surveyed claimed that the consumption of fuel-wood was reduced by 40% by using the stove. This

has an increased value for the customers, since the cost of wood has increased in some regions by more than two fold.

The picture on the top left shows one of the more recently installed fuel-efficient stoves. However, most fuel-efficient stove programs were not successful for a number of reasons. The picture below shows a stove that had been discarded after a few months of use. Firstly, many of the women using the stoves found that it created more work for them, as they had to chop the wood into finer bits to fit it into the stove and hence reverted back to used either their mud stoves or open fire for cooking and heating purposes. Secondly, during the winter, many people removed the chimney from their stoves to contain the warm smoke in the room instead of exhausting it, since they did not have enough fuel-wood to keep their homes even barely warm. Thus reducing the effectiveness of the stove programs for addressing indoor air pollution. In the village of Bheri, many of the stoves lay obsolete. This was because the metal that the stove was made of was of poor quality and got damaged after a few months of us. Since no training was provided regarding the maintenance of the stove

The success of stove programs could be seen in cases when additional features were offered, such as the use of a water warming facility were available (see picture opposite left) and also where entrepreneurs had been trained to produce and provide local maintenance of the stoves.

Some other innovation strategies in housing design

One of the homes that I visited in Bheri had an attached kitchen to the main living room. During the cooking process the door between the rooms would be closed, preventing any smoke from entering the room. The heat generated from the cooking activity would heat up the wall connecting both rooms. Since the wall had thermal mass, it would absorb the heat and slowly release into the living room, well after cooking activity had ended. When I asked those living in the homes why they did not cook inside the room where they required heating, they told me that it was to prevent dust and soot from dirtying the living room. Thus the reason behind separating the cooking and living spaces was not so much from the perspective of reducing the health risk due to indoor air pollution but for decreasing the amount of work in cleaning the room every time after cooking.

Choice of fuel for cooking and space heating

Liquefied petroleum gas (LPG), which can be purchased in cylinders, is one of the clean burning fuels that is being promoted within the communities in the Northern Areas of Pakistan. However, the adoption of LPG as a primary fuel for cooking and heating purposes has been constrained, since it is more expensive than fuel-wood and also since the market access to LPG is still limited.

On my visit to Ghulkin, I learnt about another fuel option- the 'sibakhra' shrub. This shrub has been used for decades in the community and is known for its clean burning. Very few, if any at all, women in the community had complained of suffering from respiratory or eye related problems due to the combustion of this fuel. Before the winter months the shrub is cut and collected in huge piles, as shown in the picture on the right. It is also renewable- whatever stock is cut grows back by the collection time of the next winter season.

A note on delivery of housing energy efficiency products

Organizations such as the AKPBS,P strongly believe that any housing energy efficiency product should be developed with the community. This implies that first the needs for the product are identified through consultation with the community, then prototypes are set up in households to offer demonstration and in the last phase local entrepreneurs are

recruited and provided initial support to manufacture and distribute the products.

In the consultation and prototyping phase, knowledge of existing products and their affordability has been helpful in identifying and adapting solutions. However, in order to spur local innovation community members should be provided incentives for trying techniques they have in mind. Some of the communities I visited were aware of the solutions to improve the insulation of their homes but did not have access to materials. Through the participation of community members in focus groups and technical design related work shops- design and prototyping can be facilitated and tested.

After the prototyping and testing with the community, the promotion of the product through demonstration within the community is required. AKPBS,P has annually participated in the Silk Route Festival and also in road shows to help create awareness and generate a demand for the product . The installation of products in households during the demonstration phase has allowed the monitoring of the drawbacks and benefits of the products.

More importantly, for any of these solutions to be locally sustained and innovations to be replicated and adapted in different communities throughout the Northern Areas of Pakistan, the access to micro-finance and training and support for local entrepreneurs are key. The subsidization of the products should be limited to the demonstration phase, otherwise the presence of subsidies does not allow a grass roots level market demand to be created and for the affordability and appropriateness of the solutions be addressed.

Conclusion

While studying about innovations in building energy efficiency in communities where the access to resources is constrained, I began to see that energy savings have a different reality in different communities and thus the promotion of energy efficiency needs to be tailored accordingly. I also realized that innovations are not categorized on basis of technicalities alone but also the social systems and the communication channels that are used to disseminate them. Since building energy efficiency involves a cross-section of issues regarding energy, education, health and poverty alleviation, the collaboration between different organizations is required to avoid duplication of efforts and improve efficiency.

Acknowledgements

I would like to thank the Aga Khan Program for Islamic Architecture for making it possible to spend part of my summer last year traveling across Northern Pakistan. Through the opportunity I was able to learn about parts of my own country and come in contact with people whom I had limited exposure to when growing up in Pakistan. The trip really increased my awareness of the resilience and innovativeness of some of the communities.

I would also like to thank my supervisor, Professor Norford, and my advisor, Professor Glicksman for their constant support and inspiration.

Most importantly I would like to thank the staff at AKPBS, WWF and CAI, not only for providing access to their work and the opportunity to learn from the target communities but also for sharing their vision. I look forward to working with them in the future.