INDOOR THERMAL COMFORT IN RESIDENTIAL BUILDING STOCK

A STUDY OF RCC HOUSES IN QUETTA, PAKISTAN

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Preface

The report is a part of the PhD project entitled “Methodology for the design of climate responsive houses for optimized thermal comfort in Quetta, Pakistan” being carried out at University of Liège, Belgium. The aim of the project is to improve indoor thermal comfort of free-running houses in Quetta and raise the awareness of builders about climate sensitivity.

The present findings are based on the monitoring of indoor climate, survey questionnaire and the interviews of the residents living in the houses made of reinforced cement concrete (RCC) structure. We aim to provide the readers with insights and perspectives on the existing houses, their comfort performance, comfort perception and understanding of the residents and the use of mechanical methods to optimize thermal comfort in RCC houses in Quetta, Pakistan.

Acknowledgement

We would like to thank all the respondents who participated in the survey.

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List of abbreviations

AC	Air-conditioner
AEDB	Alternative Energy Development Board
BUITEMS	Balochistan University of Information Technology, Engineering & Management Sciences
CFL	Compact Fluorescent Lamp
DHW	Domestic Hot Water
FL	Fluorescent Lamp
FY	Financial Year
HDIP	Hydrocarbon Development Institute of Pakistan
HEC	Higher Education Commission, Pakistan
HVAC	Heating, Ventilation and Air-conditioning
IAQ	Indoor Air Quality
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
NREL	National Renewable Energy Laboratory
Pak	Pakistan
PBS	Pakistan Bureau of Statistics
PWD	Public Works Department
PES	Pakistan Economic Survey
PMD	Pakistan Meteorological Department
QDA	Quetta Development Authority
RCC	Reinforced Cement Concrete
Rs.	Rupees (currency of Pakistan)
UPS	Uninterrupted Power Supply

1. Introduction

Household sector in Pakistan consumes more than half of the energy (PES, 2018). The country's population is growing at an annual rate of 2.4% which increases the housing units and household energy consumption. Quetta city is the provincial capital of Balochistan and 10th largest city of Pakistan (PBS, 2017). The urban population of Quetta is increasing at a high rate of 5.83% per annum which results in the development of new housing schemes and the construction of more housing units (QDA, 2017). However, the available information on housing in Quetta was limited and outdated. A housing survey was conducted to get insights of housing characteristics, construction typology and building materials. It was found that reinforced cement concrete (RCC) houses is the most common housing type in Quetta which is also wide spread through the city (Mahar et al., 2017) (Mahar & Attia, 2018).

This study aims to explore the indoor thermal comfort in RCC houses, comfort perception and satisfaction of the residents living in such houses. This report is part of a PhD project which aims to improve the indoor thermal comfort of free-running RCC houses in Quetta and raise the awareness of builders about climate sensitivity. The report presents the methodology of the monitoring of indoor climate, results of climate monitoring and the transcription of the interviews from the residents of 10 houses. It will be helpful to understand the existing houses, their indoor climate, comfort perception and the opinion of the residents about comfort and indoor climate.

2. Methodology

Similar to the work of (Singh et al., 2016) and (Attia et al., 2012), this study is based on two steps; selection of houses, and the monitoring of indoor climate and comfort survey. Both steps are described in detail.

2.1 Selection of houses

10 houses of various sizes from large to small were selected for this study, see Table 1. The selection criteria were based on the layout of the house, materials, location of the house, income level of the household, construction typology and the willingness of the residents to participate in the monitoring and comfort survey. All 10 houses represent same structural system, i.e. RCC frame structure, climate and are geographically located in different neighbourhoods of Quetta. The houses may represent different combination of construction and finishing materials, heating and cooling systems/ devices and housing typology, i.e. attached, semi-attached etc. The houses may also differ regarding household size, and their cultural, ethnic, religious, economic, and educational background (Mahar et al., 2018).

Table 1 List of selected houses

S. No.	Area of the house (m^2)	Household size	Monitoring period	Year & season
I.	650	11	4 weeks (2+2)	Summer 2017, Winter 2017-18
II.	408	12	4 weeks (2+2)	Summer 2017, Winter 2017-18
III.	307	8	1 year	27 Jul ’17- 26 Jul ‘18
IV.	278	8	4 weeks (2+2)	Summer 2017, Winter 2017-18
V.	213.6	7	1 year	27 Jul ’17- 26 Jul ‘18
VI.	148	12	4 weeks (2+2)	Summer 2017, Winter 2017-18
VII.	130	6	1 year	27 Jul ’17- 26 Jul ‘18
VIII.	130	7	4 weeks (2+2)	Summer 2017, Winter 2017-18
IX.	140	6	1 year	27 Jul ’17- 26 Jul ‘18
X.	63	7	1 year	27 Jul ’17- 26 Jul ‘18

2.2 Monitoring of indoor climate and comfort survey

A field survey was conducted to understand the indoor climate. Fields surveys provide "first-hand" data to understand the thermal comfort and the actual daily environment of the residents. Usually, two types of data are required for such field surveys, which are objective and subjective measurement data (Wong et al., 2016).

Indoor air temperature and relative humidity was monitored in all 10 houses for objective measurement. The monitoring was started at the same time in all houses, however, due to some on site issues the monitoring was done for 4 weeks in 5 houses, i.e. 2 weeks in summer and 2 weeks in winter. In summer, the monitoring took place from 27/07/2017 to 9/08/2017 and in winter from 27/12/2017 to 9/01/2018. This period was selected to monitor extreme hot and cold temperatures. While monitoring was continuously done round the year in rest of the 5 houses. Details of the monitoring period for each house are mentioned in Table 1. Two data loggers were placed in each house at the position where sunlight, heating and cooling devices don't affect them. One data logger was placed in master bedroom and one in living room/ lounge. The loggers were activated for delayed start and all loggers were placed in the houses before their launching time. The loggers were set to measure indoor air temperature and humidity in all 10 houses with an interval of every 10 minutes.

The measured data was then compared between internal and external environment. The ceiling fan remained on during occupancy hours and windows were mostly open during summer for cross ventilation. In winter heating was on during the occupancy hours while doors and windows were kept closed to avoid entry of cold air. However, during winter the residents sometime open a small portion of door, window or ventilator for the fresh air during heating hours.

The outdoor air temperature and humidity was also monitored for whole year by placing a data logger in well ventilated weather-proof box (see Fig. 2-3). The box was then placed on a rooftop of a building at Balochistan University of Information Technology,

Engineering & Management Sciences (BUITEMS) Takatu campus Quetta. The weather data was also taken from Pakistan Meteorological Department (PMD) and a weather station at the same campus of BUITEMS University maintained by Alternative Energy Development Board (AEDB), Government of Pakistan together with National Renewable Energy Laboratory (NREL) of United States. HOBO U12-012 data loggers were used to monitor air temperature and humidity. Figure 1 shows the data logger, Figure 2 and Figure 3 shows the weather proof box used for outdoor monitoring and the outdoor weather station at BUITEMS Takatu campus Quetta can be seen in Figure 4.

Figure 1

Figure 2

Figure 3

Figure 1, 2 and 3. HOBO U12-012 data logger and box

Figure 4

Figure 4 Weather station on the rooftop

A short questionnaire was filled, and semi-structured interviews were conducted from the residents for the subjective measurement and to understand their comfort perception. Follow up questions were asked; and respondents were encouraged to provide their input on a specific question to clearly understand the responses. Plans of all 10 houses were drawn as per the actual measurements and construction. The questionnaire and semi-structured interview comprise the questions related to socio-demographic information, construction and architectural aspects, energy problem and prices, heating and cooling systems/ devices, lighting, comfort, clothing, behavioural insights and renewable energy. The questionnaire

designed for this study was based on English Housing Survey (EHS, 2015) and was previously validated and used for a housing survey in Quetta (Mahar et al., 2017) (Mahar & Attia, 2018).

Semi-structured interview was designed and later revised and updated after discussion with local architects and building professionals practicing in Quetta. The interviews were conducted from the head of the household and some family members (if possible). Due to cultural, societal differences and time limitations it was not possible for the researchers to meet all family members of 10 households. In that case, the head of the household collected the responses from family members and then conveyed to the researchers. The semi-structured interviews were recorded and transcribed. The important findings and of the interviews are presented in this study. Appendix A presents structure of the questions used in semi-structured interview.

3 Results and discussion

The results of this study are divided in seven sections which includes questionnaire survey and semi-structured interviews (with layout plans of the houses), monitored data, control systems, clothing, energy consumption behaviour, comfort perception, energy situation and resident's satisfaction from energy prices.

3.1 Household survey and interview

This section provides basic information of all 10 houses together with detailed layout plans and the summary of responses of each household collected via questionnaire and semi-structured survey. It covers description of the house and household, HVAC systems used in the house together with energy and lighting, behavioural insights of the occupants, clothing and the perception of the residents about comfort and renewable energy.

3.1.1 House I

House-I is situated in the north of Quetta city at Airport road Quetta near Bazai Qila. The house has covered area of 650 m^2 and the household size is 11, including families of 2 brothers and their parents. The first family comprises of 5 family members including husband, wife and 3 kids. The second family comprises of 4 members including husband, wife and 2 kids. The responses were collected from one of the brothers, aged 37 (head of the family of 5) and his 2 kids. It is further mentioned that joint family system is still common in Quetta and in many other parts of Pakistan. Figure 5 and Fig. 6 present the ground and first floor plans of the house. The construction of this house was completed in 1999. The thickness of exterior and interior walls is 9" or 22.86 cm.

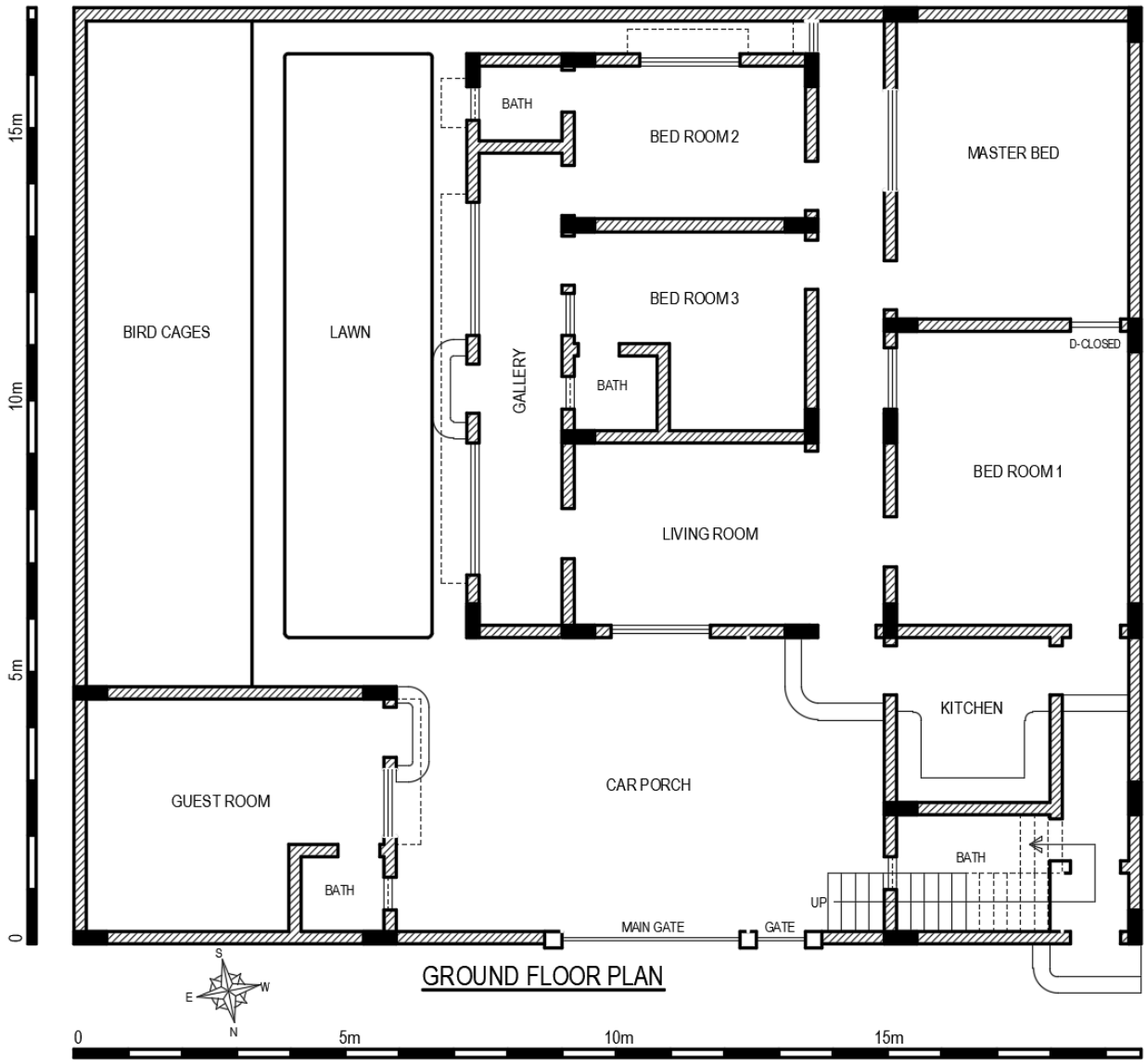

Figure 5 Ground Floor Plan of House I

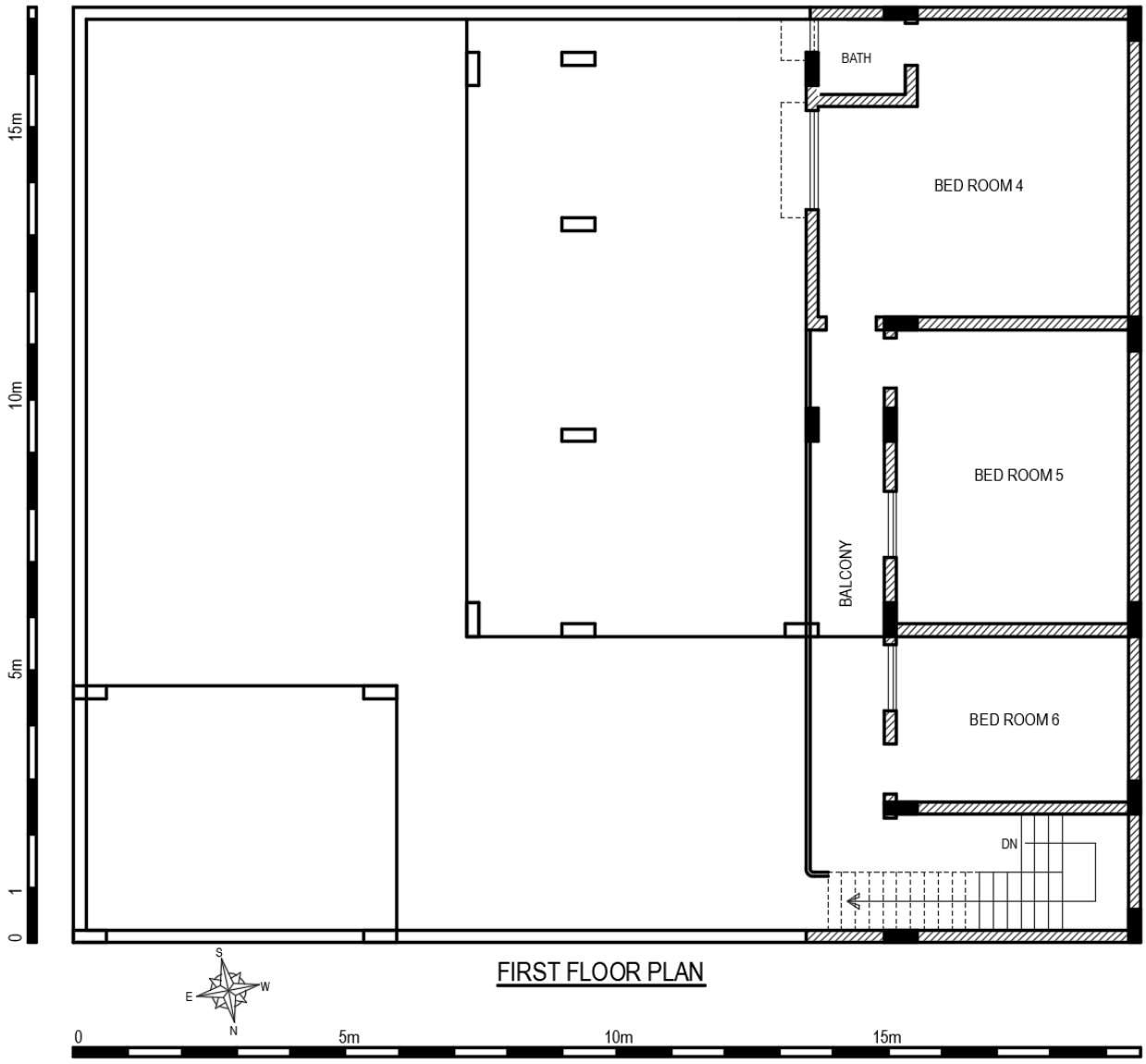

Figure 6 First Floor Plan of House I

3.1.1.1 HVAC systems, energy & lighting

All rooms on the ground floor are inhabited by the residents while the first floor is only occupied sometimes by the guests. All 6 rooms including living and guest room are heated during winter. There are six gas heaters in the house, four of them are gas fired direct heaters (radiant) while the remaining two work on both gas and electricity (convectors). The convector heaters remain on during occupancy hours even at the night while sleeping to maintain the

indoor temperature. The radiant gas heaters are mainly used during occupancy hours or in case of electricity outage. There is no central heating in the house.

In summer ceiling fans remain on when rooms are occupied even at the night. Ceiling fans are fixed in all rooms. In addition, there are 2 bracket fans, 2 pedestal fans, 4 exhaust fans and one air cooler in the house.

There are 2 geysers/ water boilers in the house for hot water. Both remain on throughout the year as kids prefer to take shower with warm water in the morning. The residents try to keep the old/ paid energy bills but it's not always the case. They are unaware of the pricing systems and cost of electricity per kWh or gas per m^3. The household is slightly satisfied from the electricity bills and neither satisfied nor dissatisfied from the gas bills. Natural gas is used for the cooking and there is a microwave for heating up the meals. There is no oven in this house.

The tenants face regular load shedding of 8h per day in summer and 4-6h per day in winter. The household use generator during electricity outage hours mostly in summer. There is also an Uninterrupted Power Supply (UPS) combined with the rechargeable battery but generator is mainly used during electricity outage. The household face low gas pressure sometime during cold winter. In such situation gas heaters are turned off during cooking hours. There is also a Liquefied Petroleum Gas (LPG) cylinder to cook meals during very low gas pressures or outage of gas.

Some family members stay at home during the day and use lounge (living room) and kitchen most of the time. Television (TV) stays on during day time if someone is using lounge. Energy savers/ Compact Fluorescent Lamp (CFL) and Tube Lights/ Fluorescent Lamp (FL) are used in the house for lighting. In two rooms and kitchen lights are turned on during the day due to lack of day light.

The household have taken no measurements for energy saving or improvement except replacing old Incandescent light bulbs with CFL lights. However, the residents would like to do some energy renovations if they get better guidance and can afford the expenses. The residence prefers the finish and quality of the current materials and don't want to compromise on the finishing quality of the materials. That mean the suggested alternative materials should also provide the finish quality as cement plaster, paint or tiles.

3.1.1.2 Behavioural insights

When any room or portion of the house is unoccupied the lights are kept off. Adults take care of it and try to turn off the extra lights, fans and appliances. Only one person in the house is more concerned about turning off extra lights and appliances. Rest of the family members are quite reluctant in this matter. Someone always stays at home, so some lights and appliances are in use all the time. While leaving house for few hours the residents turn off extra lights and appliances which are not needed.

The heaters remain on most of the time and specially when the rooms feel cold. The gas radiant heaters are turned off at night, but the convector heaters remain on. Windows are opened in summer mainly in evening and night. In winter the windows remain closed to avoid cold air.

3.1.1.3 Comfort and clothing

In cold winter, the living room of the house feels slightly cold which tends to keep the heating on. In summer, the living room feels normal. In winter the master bedroom remains very cold since there is underground tank beneath the room. In summer, it feels slightly warm in the same bedroom. Windows are opened in the evening and night for comfort.

In summer, Bedroom 2 at ground floor is hotter compared to other rooms as there is no room above it on first floor and the roof is exposed to sun. The master bedroom is colder in winter compared to other rooms.

The household is slightly dissatisfied with the existing cooling and ventilation methods and systems in the house and slightly dissatisfied with the existing heating devices and arrangements. The reason for dissatisfaction was not given.

In winter, both men and women wear Shalwar Kameez made of thick fabric or wash 'n' wear clothing together with pull overs, sweaters, Shawl or jackets. In summer, clothes made of cotton, lawn and wash 'n' wear. Men sometime also wear trousers and T-shirts. Women wear Dupatta in summer and mostly use Shawl in winter. Kids use jeans, Shalwar Kameez, and shirts with jackets or sweaters in winter. While in summer Shalwar Kameez, 3 quarter pants or shorts with T-shirts.

3.1.1.4 Renewable energy

The household knows very little about the renewable energy and its sources. Currently, the residents are not considering any alternative means except relying on current energy systems. However, they might think about using solar energy if it is affordable. In their opinion there is no energy crisis in Pakistan and they don't understand the actual reasons behind the load shedding. The household prefers the gas water boiler/ geyser instead of solar water heaters.

3.1.2 House II

House II is in the south of Quetta city in Mir Colony near Govt. Degree College Sariab road. The house was designed by a local architect and was built in 2004. The covered area of the house is 408 m^2. The household size was 12, including families of 2 brothers, one unmarried brother and their parents. The first family comprises of 4 family members including husband, wife and 2 kids. The second family comprises of 5 members including husband, wife and 3 kids. The responses were collected from two brothers, aged 33 and 37. The thickness of walls is 9” or 22.86 cm. Figure 7, shows the existing layout of House II.

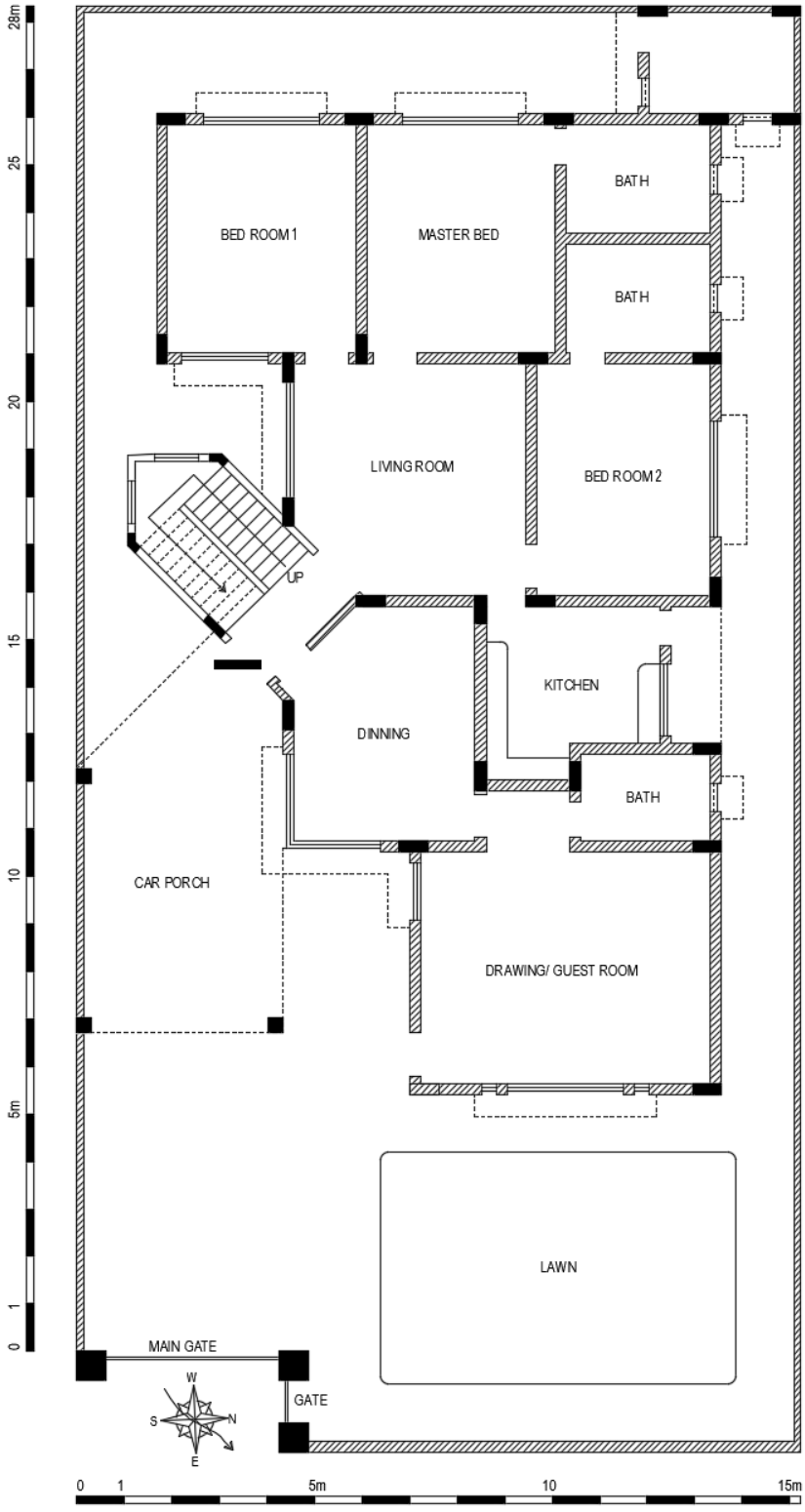

Figure 7 Ground Floor Plan of House II

3.1.2.1 HVAC systems, energy & lighting

All rooms in the house are heated during winter including lounge (living room) and guest room which is typically called drawing room in Pakistan. There are total 6 heaters in the house, which included one convector heater and five radiant heaters. Heaters are used in cold season mainly during December to February in morning and evening. The gas convector heater remains always on during occupancy hours.

Ceiling fans are fixed in all rooms for ventilation. Fans remains on during occupancy hours. There are 3 exhaust fans, one in kitchen and 2 in rooms and 2 air coolers in master bed and bedroom-1 which are used during hot summer months between May to August. Both air coolers are fixed in windows. That mean a small portion of window in master bed and bedroom-1 can be opened. Mainly there are no window projections except on the window of master bed and living room. The doors and window frames used are made of wood.

There is one gas water heater in the house which remains off during hot days of summer between June to August. Sometimes in summer, the water heater is turned on to take warm shower in cold morning. It is made of thin material sheet and fixed in an open area which makes the water warm in summer day hours due to exposure of water heater and pipelines to the sunlight. Th family usually keeps the old energy bills for personal record. The residents are unaware of the prices of electricity and gas. According to residents the billing system is complicated, and prices vary few times in a year. According to them the energy consumption is less, yet the bills they receive are high. The household is very dissatisfied with the electricity prices and slightly satisfied with the prices of natural gas. Cooking is mainly done using natural gas. Microwave and grill are also used sometimes.

There is 6h load shedding per day in winter and 8h per day in summer. The load shedding hours are fixed. In case of some crisis, bad weather or problem in national electric supply grid there is extra load shedding. During electricity outage rechargeable lights are used to light the indoor areas. In summer, all sit in the living room and windows are kept open for ventilations.

The residents face gas outage in case of some fault or maintenance, but such outage hours are announced by public notice via newspapers. In cold winter household faces low gas pressure from evening till mid night and specially during cooking hours. LPG cylinders are used for cooking during long outage of gas. The radiant gas heaters are turned off in case of low gas pressure at the time of cooking while the gas convector heater remains on.

Some family members stay home during the day hours and mainly use living room, car porch area, courtyard and kitchen. Charpai (local bed) is used to sit in the porch or courtyard during day time.

The household use CFL and FL lights and light emitting diode (LED) lights in one room. However, the CFL lights are mainly used. Lights are turned on during the day as the windows projections are not enough to stop the direct sunlight entering to rooms. Curtains are closed to avoid direct sunlight. In rooms the access to natural light is not enough, even when the curtains are open the residents need to turn on the lights while performing daily activities such as preparation for meals, cutting vegetables, reading etc.

No energy renovations were made in the house. The roof was white washed to reduce heat from solar radiation and lights were changed to CFL and LED. The residents are willing to do energy renovations if affordable and if the materials are locally available in Quetta, for example, double glazed windows are not locally available. The resident prefers to live in RRC houses and don't want to compromise on built quality and finishing of the materials.

3.1.2.2 Behavioural insights

During inoccupancy hours the lights and fans remains off. However, the lights in courtyard, porch area and outdoor remains on. Servant rooms is always in-use even if the family is away for holidays. Only 2 persons in the house are cautious about energy usage and turn off extra lights. They remove TV plugs at night while the mobile charges stay connected even not in use.

Heaters and fans remain on in winter and summer if the room is in use. In cold winter the heaters are turned on 1-2h prior to the use the rooms to achieve the comfortable indoor temperature. Heaters are turned off if the rooms are not in use. One heater in living rooms stays on during the nights. The living room is well ventilated so luckily no incident occurred.

Natural ventilation is preferred so that in summer windows are opened for fresh air. Some days are stormy, so windows are closed to avoid the dust entering in indoor places. In winter, all windows are sealed with thick cloth/ fabric and plastic to avoid cold air entering in rooms.

3.1.2.3 Comfort and clothing

The living room feels very cold in winter while it feels normal in summer. It feels very cold in winter maybe due to its marble flooring and in summer the same marble floor keeps is cooler. The master room feels very cold in winter. Heaters are turned off at night except living in room. As the temperature goes down in night the residents feel cold in the rooms while asleep. In summer, the same master bed feels hot which makes it difficult to sleep inside during electricity outage hours. Doors and windows are kept open at night to get comfort inside the bedroom. Guest room is colder than all other rooms and bedroom-1 at the back of the house remain warmer in summer and colder in winter.

The household is slightly satisfied from the existing cooling and ventilation in the house. They said putting air coolers in all rooms would be better to get comfortable inside the rooms in summer. During July and August residents feel suffocated inside the rooms due to heat less wind cycles. They are dissatisfied with the heating system or devices used and they think the room with gas convector heater is better to sleep in winter as it maintains the indoor temperature during the night.

In winter male wear Shalwar Kameez, warm and thick clothes such as Khadi or Khaddar with Shawl while in the rooms. Sometimes also wear socks while awake or sitting in the house. Kids always wear warm clothes and socks as they play in courtyard or move around the house. They wear long pants with shirt, jacket and sweaters in winter while sleeveless shirts, shorts or jeans in summer. Female wear warm woollen clothes in winter and cotton in summer. In summer, male mainly wear clothes made of cotton and mixed fabric.

In winter, some family members always wearing sweater even sleeping at night. Female members in the house feel colder maybe because they work in kitchen and use water to do the dishes. They prefer to sit closer or beside the heaters. Kids mostly remain active and run around inside the house, so they don't complaint about the cold in winter. In winter, sometimes one facing to the heater and after few minutes realize that their back is cold or if one is not sitting close to the heater then also feel colder inside the house. Ironing clothes in summer is more difficult and one who does it feel hotter and get sweat.

3.1.2.4 Renewable energy

According to the opinion of residents, using solar energy is good. The houses should be well designed to get benefits of natural ventilation. They prefer grid connected electricity and using UPS or generator than installing solar PV. If they would get some subsidy they would install solar PV or if government provide it free of cost. They mentioned that there are some Non-Government Organizations (NGOs) providing solar PV and batteries to some villages and providing solar operated fans and air coolers. Those fans are usually of 12 watts. NGOs introduced solar technology in the villages of Districts Nushki, Chagai and Kharan and now local people are installing solar energy as many of the villages have no electricity or there are longer outage hours such as 20h per day. Those people are very much satisfied with the solar energy.

Th respondents thinks that government is responsible for the energy crisis in Pakistan. Several projects were announced but the execution was not done effectively. The issue became

very serious with the increasing demand and users. New dams were not built to generate enough hydropower. Either we buy electricity from Iran or install solar or wind projects to solve the energy problem they added. In their opinion, Solar PVs are fine, yet they prefer grid connected solar systems rather than installing individual units. However, they are not sure about the solar water heaters. They think the life cycle of a solar water heater is short and once they get problem it cannot be fixed. They have doubts about the performance of solar water heaters.

3.1.3 House III

This house is situated in Shehroze Villas housing society at Spini road Quetta. The covered area of the house is 307 m^2. The household size is 8 family members with a nuclear family of parents and their 6 children. The responses were collected from and from two sons aged 31 and 26. The house was constructed in 2004 and was designed by a local architectural studio. The thickness of walls is 9" or 22.86 cm. Figures 8-10, shows the existing layout of the house.

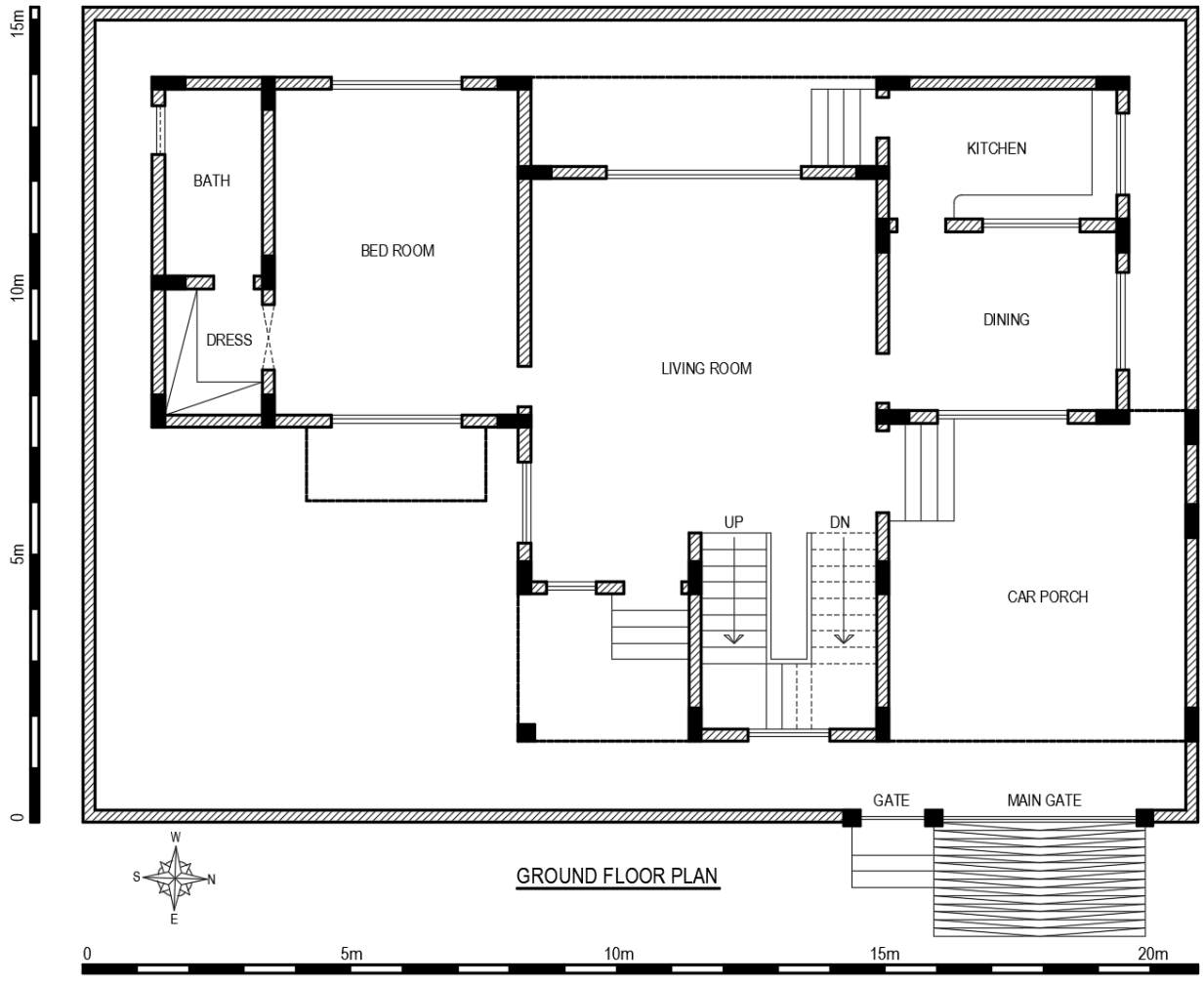

Figure 8 Ground Floor Plan of House III

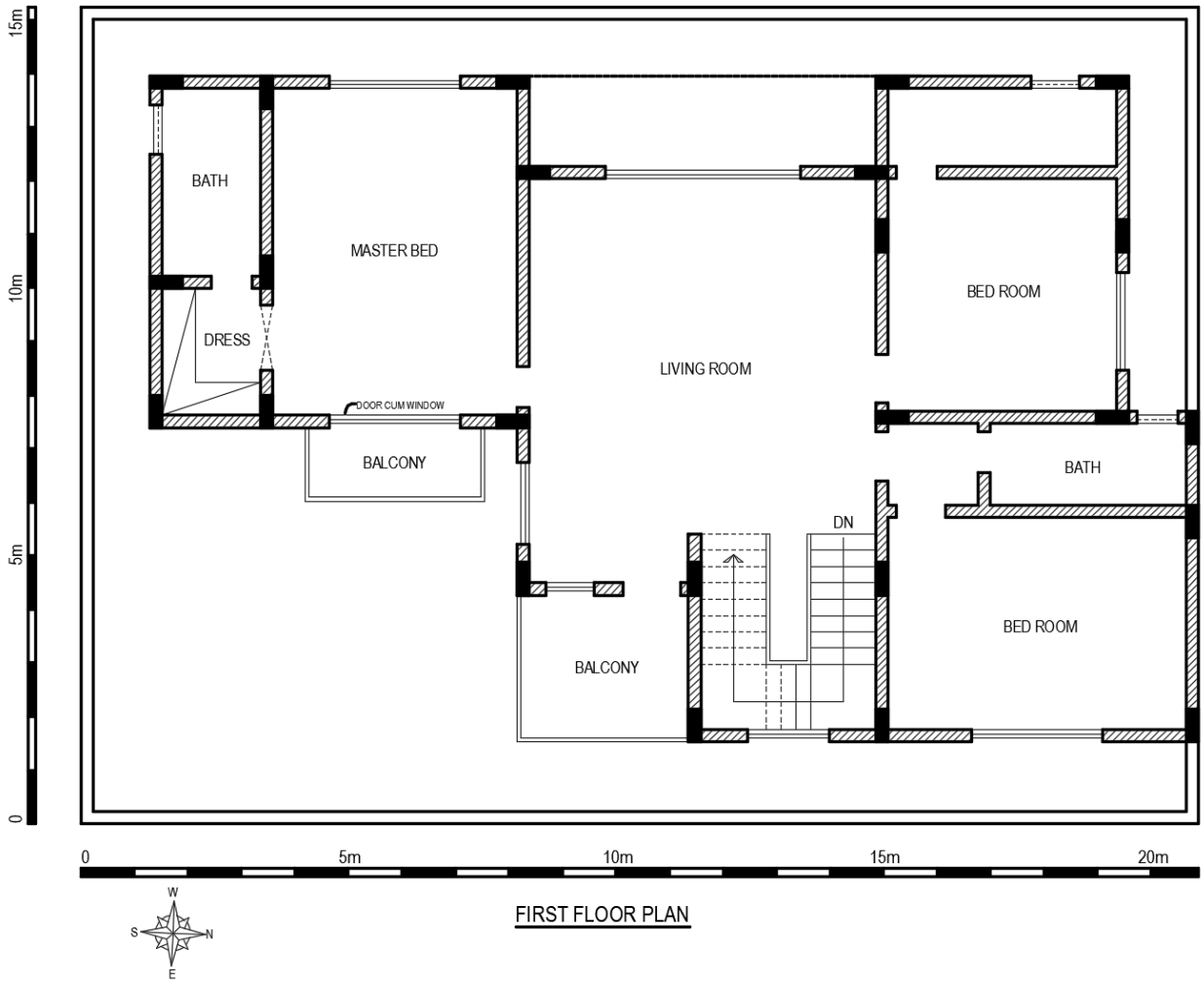

Figure 9 First Floor Plan of House III

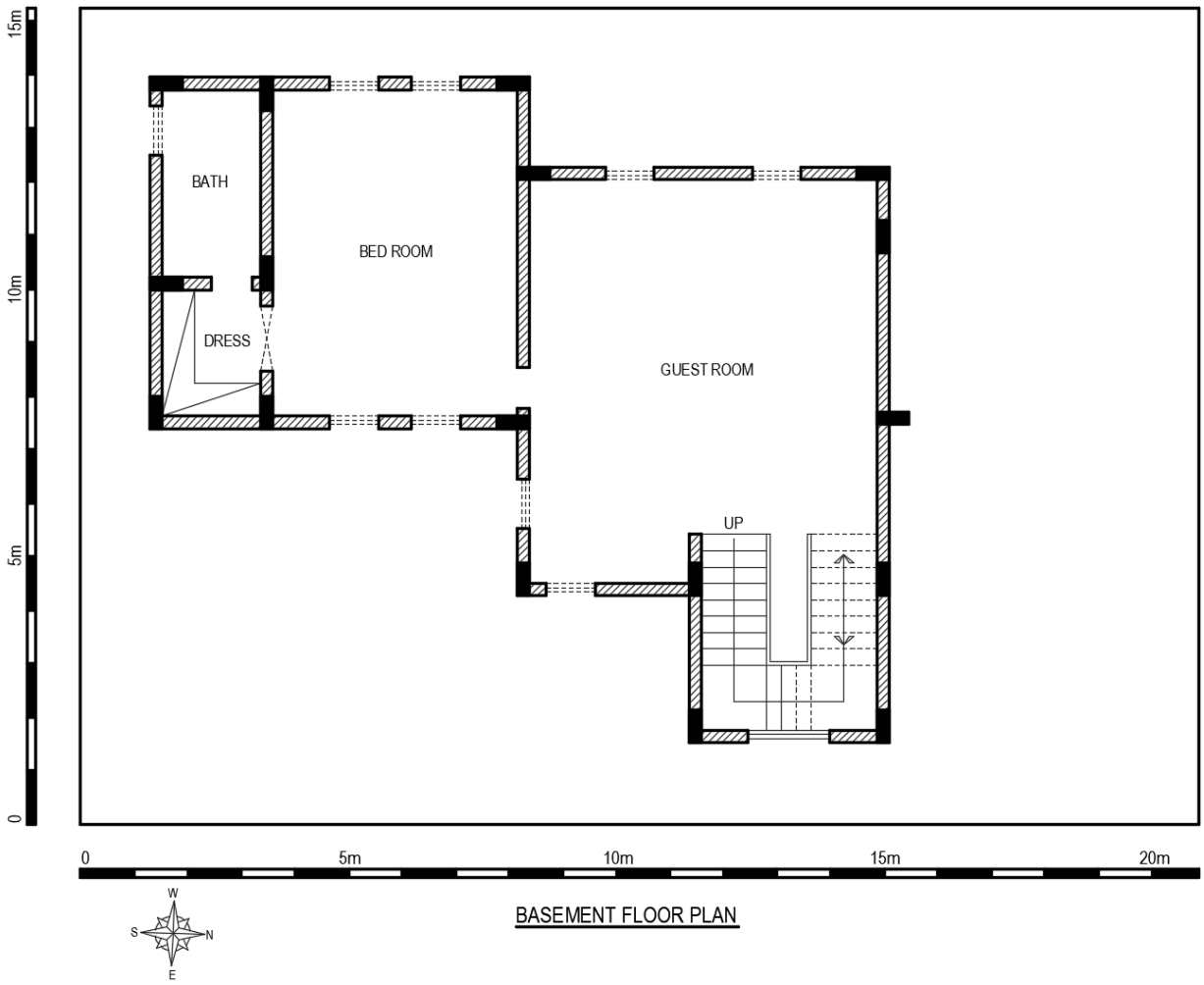

Figure 10 Basement Floor Plan of House III

3.1.3.1 HVAC systems, energy & lighting

All rooms are heated in winter. There is one convection heater and rest of the heaters are radiant gas heaters. All rooms are equipped with ceiling fans. There is no air cooler but there are 3 air conditioners in the house. A room at first floor is mostly hotter in summer and cooler in winter as it is exposed to the sun and wind.

There are 2 water heaters in the house both remain on in summer as well since the residents also like to take warm shower in summer. Old energy bills are usually kept but it is not

always the case. The residents don't know the prices of electricity and gas and the billing system. The response to the satisfaction level from electricity prices was neutral while the residents were slightly dissatisfied with the prices of natural gas. Cooking is done on natural gas and there is a microwave to heat up the food.

The household experience 6-8h per day electricity outage in summer and 4-6h per day in winter. Yet, the household own a solar PV system backed by rechargeable batteries to fulfil the electricity demand during outage hours. So that, the residents do not face the problem of load shedding and it doesn't affect their daily life. There is problem of low gas pressure in winter and the residents turn of room heaters to finish the cooking if the low gas pressures occur during cooking hours. LPG cylinder is also used for cooking during low gas pressures.

Three types of lights used in this house are CFL, FL and LEDs. Lights are turned on during the day in the basement and some parts of the house due to less access of natural light. It also depends on the activity in the room, if someone is reading, cutting vegetables then lights are turned on.

The roof of the house was white washed, and some lights are replaced with LEDs. Solar PV backed by rechargeable batteries is installed to power the house during electricity outage hours. The residents are willing to do energy performance renovation and insulate the house. However, they prefer to live in RCC houses and prefer the durability and finish quality of cement and concrete.

3.1.3.2 Behavioural insights

The residents don't care much about the extra lights and appliances as the household is also backed by solar PV. Adults mostly take care of it and turn of extra lights and appliances. One person in the house is more concerned about it. While leaving house for few hours or few

days only water heater and refrigerator stays on. They try to turn off the extra lights, but they are not so concerned about it.

Heaters are on 8h-12h per day and if the room is not in use for 1-2h. Th household prefer controlled environment by using air conditioner in summer. Residents prefer to enjoy natural ventilation when the air is clean and without dust particles. One of the reasons they mentioned for air conditioning is to keep the comfortable humidity level since humidity remains low in Quetta due to its dry and arid weather.

Windows are opened in summer only but not every day and only in some parts of the house. In winter the windows remain close to avoid cold air.

3.1.3.3 Comfort and clothing

In winter, the living room feels very cold since the house has no insulation. The same lounge feels very hot in the summer. The bedrooms also feel very cold in winter and very hot in summer, specially the bedrooms at first floor due to exposure to sun and wind. The tenants are very dissatisfied with the existing cooling and ventilation systems and would like to improve it by using some alternative means rather than relying mainly on-air conditioning. They are fairly satisfied with the heating facilities in the house, yet they plan to put gas convector heaters in all rooms.

In winter, men usually wear Shalwar Kameez with pull overs, sweaters, jackets and Shawl. And Kids, wear jeans, shirts with sweater and jackets. While women wear Shalwar Kameez and woollen fabric. In summer, men use jeans, trousers, 3-quarter pants and t-shirts including Shalwar Kameez. Kids prefer jeans, t-shirts, shorts, 3 quarter pants. Women wear Shalwar made of lawn or cotton.

3.1.3.4 Renewable energy

The tenants have good knowledge of renewable energy technologies and have installed solar system in the house. The existing solar system contains 10 plates and it has the power of 4 kilo-watt. There are 4 rechargeable batteries to store the electric power. According to residents, the initial cost was high, yet they could afford it. They think that renewable energy technologies can solve the energy problem of Pakistan. They have no plans to install solar water heater, also due to lack of sunlight in the house. As the houses are built next to each other and there is the problem of not getting enough sunlight in the houses.

3.1.4 House IV

This house is situated in Jinnah Town at Samungli road Quetta. The total covered area of the house is 278 m^2. There are 8 family members living in this house including 3 kids and 5 adults. The responses were collected from the adult member of the house aged 38y who also helped to get opinion of other family members. The house has a basement and ground floor. The construction of this house was completed in 2004. The thickness of exterior walls is 13.5" or 32.29 cm while the thickness of interior walls is 9" or 22.86 cm. The layout of the house is shown in figures 11 and 12.

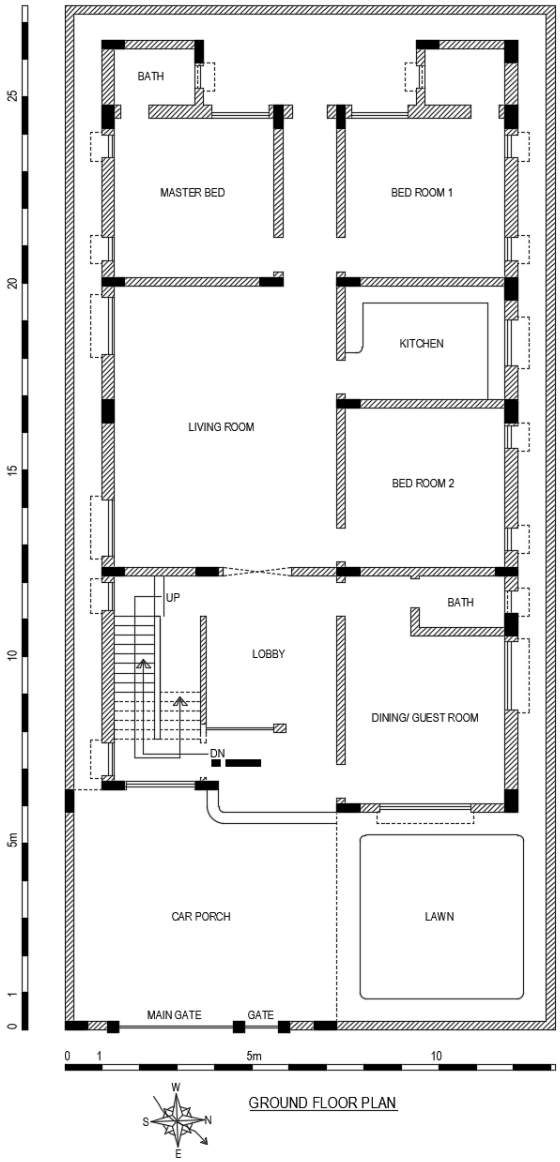

Figure 11 Ground Floor Plan of House IV

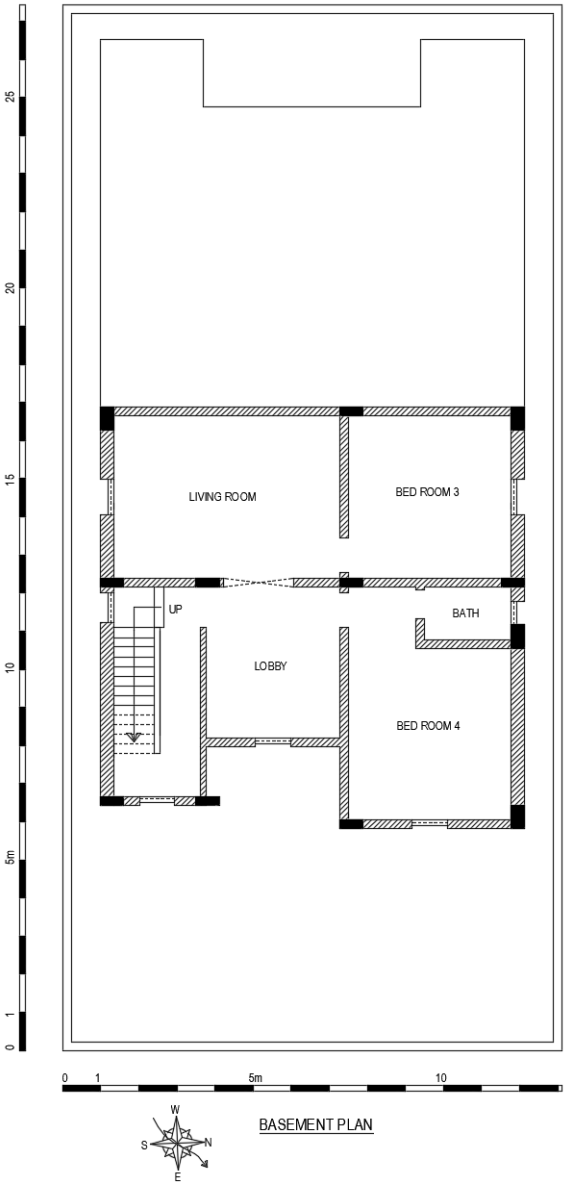

Figure 12 Basement Plan of House IV

3.1.4.1 HVAC systems, energy & lighting

The residents own 5 heaters in total which included 3 convector gas heaters and 2 radiant gas heaters. Heaters run usually from 7h-9h in the morning and then 17h-23h in the evening. In evenings more, heaters are in use. The heaters are supplied with a long gas pipe which makes them handy to move and place in any corner of the rooms.

All rooms are ventilated in summer by using ceiling fans while occupied. Fans run whole night and during the occupation hours if needed. Rooms need more cooling and heating for better sleep. Living room also need more heating and cooling while in use.

Water heaters are on round the year to supply warm water. The normal water feels cold, so residents prefer to take shower with warm water in summer. The residents do keep the record of energy bills. They are slightly satisfied with the price of electricity and very satisfied with the price of natural gas. Cooking is mainly done by using natural gas. The residents are not aware of the energy prices, according to them electricity billing is between 7-8 or 5-8 rupees (Rs.) and the prices keep changing.

The household experience 4h load shedding in winter and 6-8h load shedding in summer. The house is backed by solar system which includes rechargeable batteries to get uninterrupted supply of electricity during outage hours. The outage hours are not fixed according to the residents. While as per common practice the load shedding schedule is followed in all areas and the hours are fixed. The residents of this house think the load shedding hours are not fixed, maybe they are not aware of it since they get continuous supply of electricity due to use of solar energy.

Low gas pressure is experiences in winter, mostly in December and January and during cooking hours. Gas outage may occur sometime but it's not frequent. 1-2 weeks in winter the gas pressure gets very slow which makes it difficult to cook meals and heat the indoor spaces. Stove with kerosene oil or LPG cylinder is used for cooking during low pressure or outage of gas. Rooms are not heated when the gas pressure is very low since the heater don't provide enough heat the residents prefer to warm themselves by wearing more clothes. Convector heaters are mainly used however the radiant gas heaters are turned on when it is too cold as these heaters can heat up the spaces faster compared to convector heaters.

Between 9h-13h all of family members are away for the work or school. So only refrigerator stays on. CFL, FL and LED lights are installed in the house. While LEDs are mostly used. The tenants are willing to do the energy renovations even if the initial costs are high. According to them, materials are not locally available and there is lack of knowledge about insulation and energy renovation. They prefer the finish quality of current materials, yet they are open to use new materials. No measures are taken to control heat gain from walls and roof.

3.1.4.2 Behavioural insights

The lights and fans remain off when there is no one in the room. While going out for few hours refrigerator and the light outside the house and in courtyard stays on. If family is going out for few days, then all appliances are turned off. The house receives enough day light and there is no need to turn on lights during day time. Extra lights and appliances are turned off in the spaces which are not in use. Heaters are turned off before going to bed. Convector heaters stay on during cold nights. All heaters stay on if the room is not in use for 1-2h as spaces get cold very fast if the heating is off and reheating takes some time.

Fans remain on in summer while using the space. Fan in living room mostly stays on even not in use. Windows are opened in summer for ventilation mostly in evening and night. Dust may enter in rooms during summer and winter yet opening windows in necessary to sleep inside in summer. Only using fan in summer is not enough to sleep inside the rooms. In winter, the windows are kept closed to avoid dust and cold air. Windows are also closed to avoid mosquitoes and flies at different times of the year. For example, during change of seasons the number of mosquitoes increase.

3.1.4.3 Comfort and clothing

The living room of the house feel slightly cold in winter. Sitting closer to heaters can make more comfortable. During low gas pressures living room feels colder. In summer, it feels

very hot in the living room. According to the residents its due to hot weather only. In winter, the bedrooms feel normal if the heating is on. The same bedrooms feel very hot in summer.

The residents are fairly satisfied with the ventilation system in the house and more satisfied with the heating since they started to use convector gas heaters which stay on during night and they can also set a specific temperature. Old aged, females and kids in the house feel colder and they also feel hotter in summer. During very hot summer all family members sleep in the basement. In winter, women, kids and old aged family members always wear sweaters or Shawl while inside the house.

In winter, men wear woollen and thick clothes or Pant, shirt with jackets and sweaters. Kids wear pant, shirt with jacket or sweater. Women wear Shalwar Kameez made of thick or thin fabric according to the season. Men wear pant, t-shirts, trousers and short in summer while kids wear shorts and t-shirts.

3.1.4.4 Renewable energy

The household installed solar PV to fulfil the energy demands during outage hours. According to them solar energy can solve the energy problem of Pakistan. Individual solar systems designed according to the requirements of a house should be installed in all houses to save the energy problem. Since, the initial cost is high so many people don't think about solar energy but once they know the benefits, they will surely adapt it. The residents of this house are willing to use solar water heater in case there is no alternative solution for hot water. According to them the existing gas water heaters work fine so there is no consideration of using solar water heaters. They said in case of unavailability of gas solar water heaters can be a good alternative.

3.1.5 House V

The house is situated in the street called Sirki Kallan at Sirki road near Double road Quetta. It has the covered area of 213.6 m^2. The household size is 7 including 3 kids, husband wife and grandparents. It was designed by the owner's son who was student of architecture at that time. The construction of house was completed in 2008. The thickness of exterior walls is 9" or 22.86 cm and of interior walls is 4.5" or 11.43 cm. The ground floor and first floor of the house are shown in figures 13 and 14.

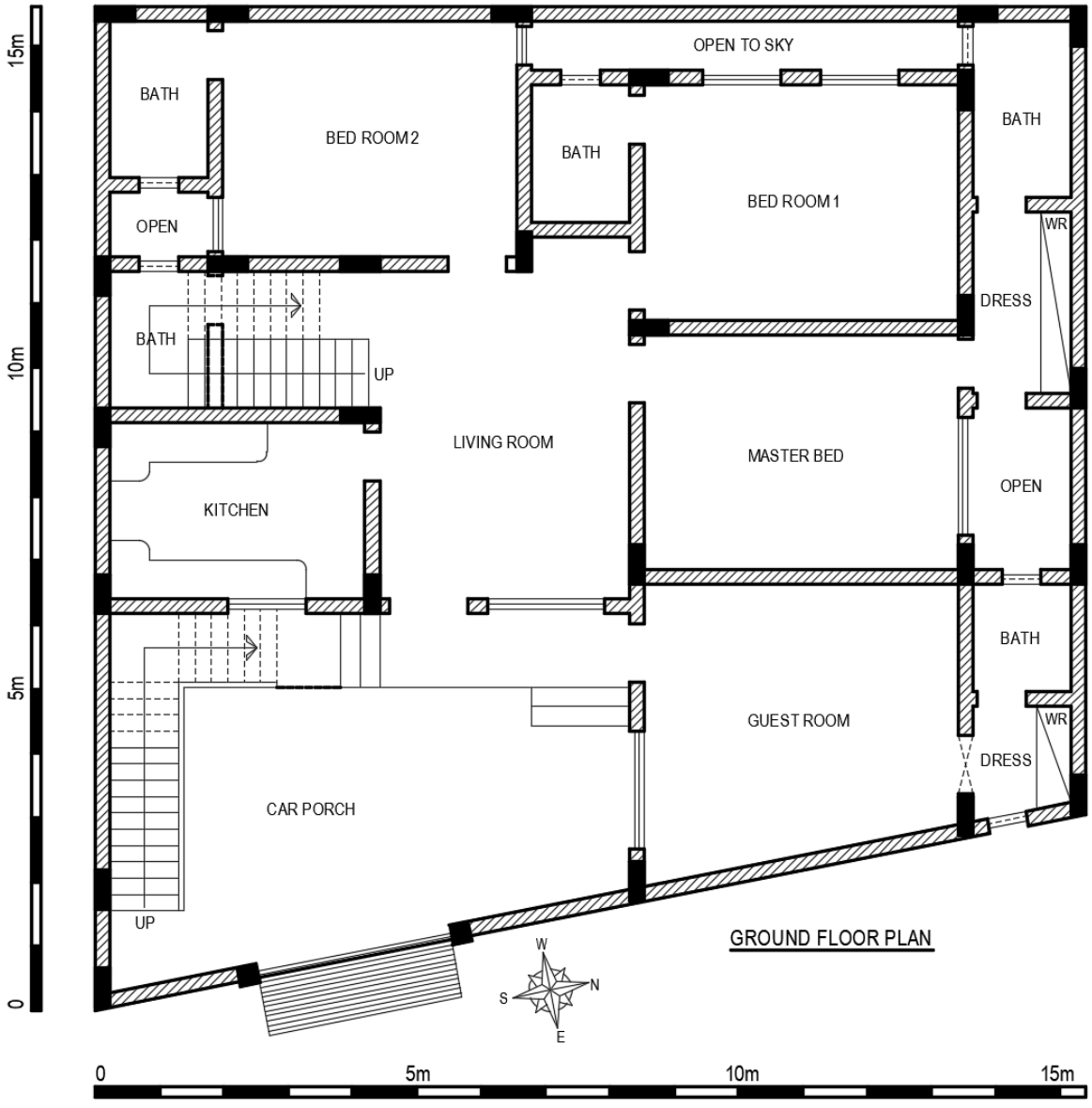

Figure 13 Ground Floor Plan of House V

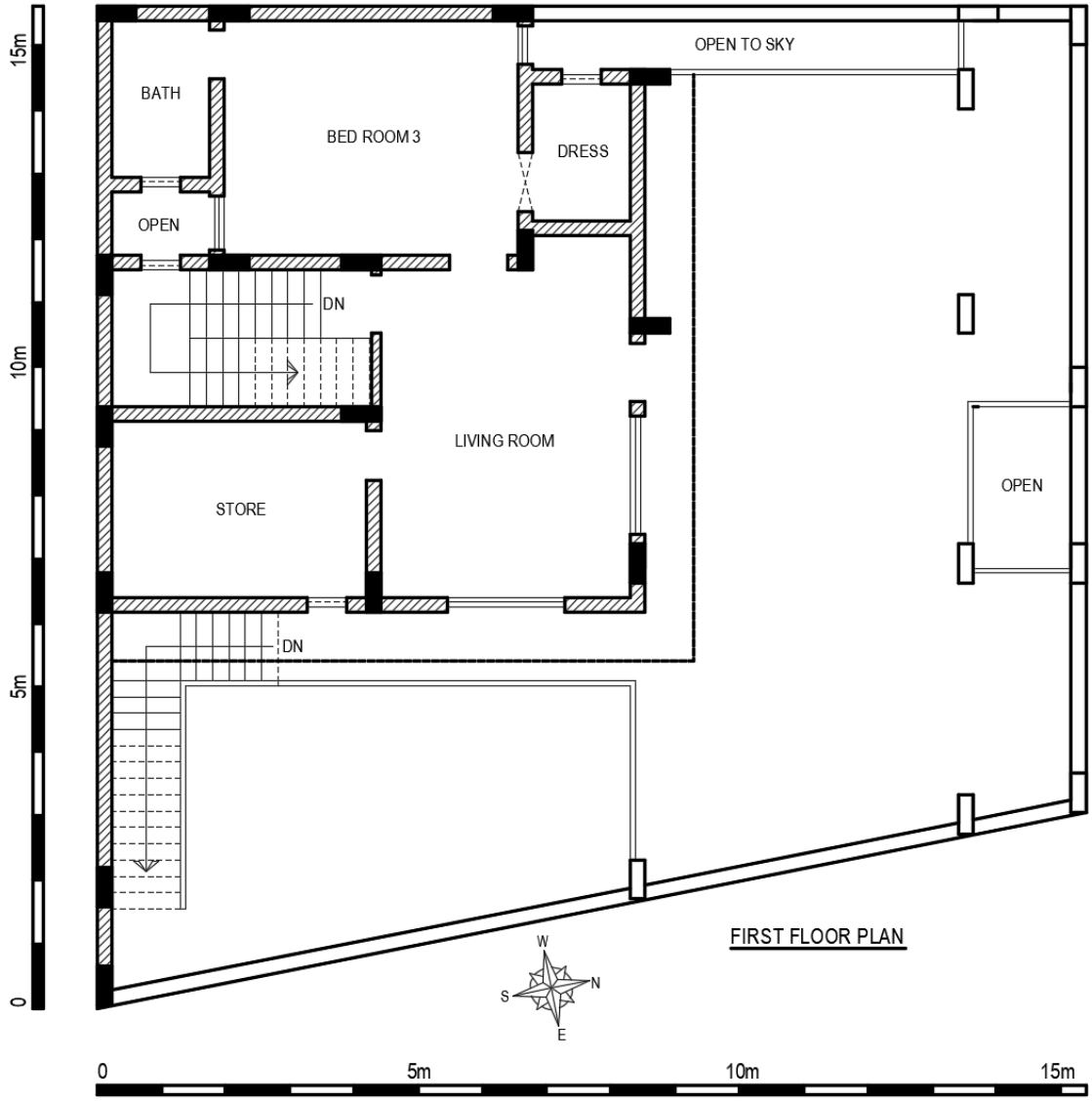

Figure 14 First Floor Plan of House V

3.1.5.1 HVAC systems, energy & lighting

In winter, 3 rooms are mostly heated including 2 bedrooms and one living room. All heaters are radiant gas heaters so only gas is used for heating. Heaters in rooms always stay on and the one in living room is on when the room is occupied.

All rooms are equipped with ceiling fans and there are 2 air coolers in the house. Pedestal fan is used sometime at first floor while sitting outside in evening. Air coolers are installed in the

rooms at first floor and used during evening or afternoon in hot summer. Mostly the rooms at ground floor are in use. Fans remain on during occupancy hours. The first floor is recently constructed, and the rooms are exposed to sunlight so that need more heating and cooling.

Domestic hot water (DHW) is provided by water boiler operates on gas. Mostly boiler is turned off in summer but turned on sometimes if hot water is needed, for example taking shower in cold morning or for laundry. The household keep record of the paid energy bills and is slightly satisfied with the electricity prices while very satisfied with the gas prices. However, they mentioned that in winter gas bills are very high due to higher consumption of gas. The residents don't know the pricing system or price of one kWh of electricity or one m^3 of gas. The cooking is done on natural gas and there is one oven sometimes used for baking.

The household faces 6h load shedding in summer as well as in winter. Load shedding hours are fixed. Rechargeable lights and gas lamps are available in the house. Mostly rechargeable lights are used if the load shedding occurs in evening and nights, since these lights are handy and can easily be placed where necessary. Windows are opened for ventilation when there is no electricity in summer.

Low gas pressure is common in winter and during very cold days. There is interruption of supply in case of maintenance and some faults. Heaters stay on while during low gas pressure but sometime heater in one room is turned off during cooking time. LPG cylinder is also used during very low gas pressures or outage hours for cooking meals. Gas pressure is mainly low between 19h-23h in the evening as well as during breakfast and lunch hour but it is very low during dinner time.

Four family members stay in home during the day, including 3 adults and one child. Kitchen, bedrooms and living room remain occupied during this time. Press iron, and TV is used during this time.

There are CFL, FL and LED lights in the house. Two incandescent bulbs are also used each of them is placed in courtyard and outdoor. The roof of first floor is white washed to reduce heat gain through solar radiation. The house has ducts for air and light. However, whenever it feels hotter a new coat of lime is applied on the roof. Residents are willing to do energy renovation and apply insulation if they can afford the cost. However, they are not sure about using alternative materials than concrete, cement and tiles.

3.1.5.2 Behavioural insights

Extra lights and appliances are turned off since there are 4 adults in the house, so they take care of it. While going out for few hours the light in living room and refrigerator stays on whereas when leaving house for few days refrigerator and boiler is also turned off. Lights are not turned on during the day except in one room where there is not enough day light access.

All heaters are turned off before going to bed. Windows are opened for natural ventilation in summer and closed if there are more dust particles in the air. Windows are mostly opened in evening and remain open during the warm nights while always remain closed in winter to avoid heat loss.

3.1.5.3 Comfort, and clothing

In both winter and summer, the living room feels comfortable when the heating is on or when windows are open for the cross ventilation. The bedroom feels slightly cold in winter due to difference between indoor and outdoor temperature and temperature drop at night. It feels comfortable if the heating is on. The same bedroom feels hot in summer.

The residents are fairly satisfied with the ventilation and heating systems in the house mentioning that using fans and exhaust fans are enough for comfort in the house in summer and turning on heaters to maintain the comfortable temperature in winter. However, the

spaces get cold when the heating is off. In winter, the females and old aged family members also wear Shawl while in the house.

Alike all other households' men and women mostly wear Shalwar Kameez. In winter, warm clothes and in summer mixed fabric. Men also wear pant, trousers and shirts. Women prefer cotton or lawn fabric in summer. Kids wear clothes made of cotton fabric in summer and warm clothes with jacket or sweaters in winter.

3.1.5.4 Renewable energy

According to the inhabitants of this house, using renewable energy is not yet common in Pakistan. However, using such methods can be beneficial to solve the energy crisis and will help to lower the carbon footprints. They are willing to use renewable energy technologies in their house providing the initial cost is bearable or subsidy is provided. The residents are aware of the potential of solar energy and wind energy in Quetta and they know some people who are using one of the methods to fulfil their energy needs. They mentioned that solar powered farming and agriculture is becoming common in many parts of Balochistan.

3.1.6 House VI

The house is located in Gulbagh Colony, Kakar Town at Samungli road Quetta. The total area of the house is 148 m^2 and there are 12 family members including families of 2 married brothers each with 4 and 5 members one single brother and 2 grandparents. The current residents bought the house in 2016, according to them it was built in 2006. The wall thickness for exterior and interior walls is 9" or 22.86 cm. Figure 15 and 16 presents the plans of the house.

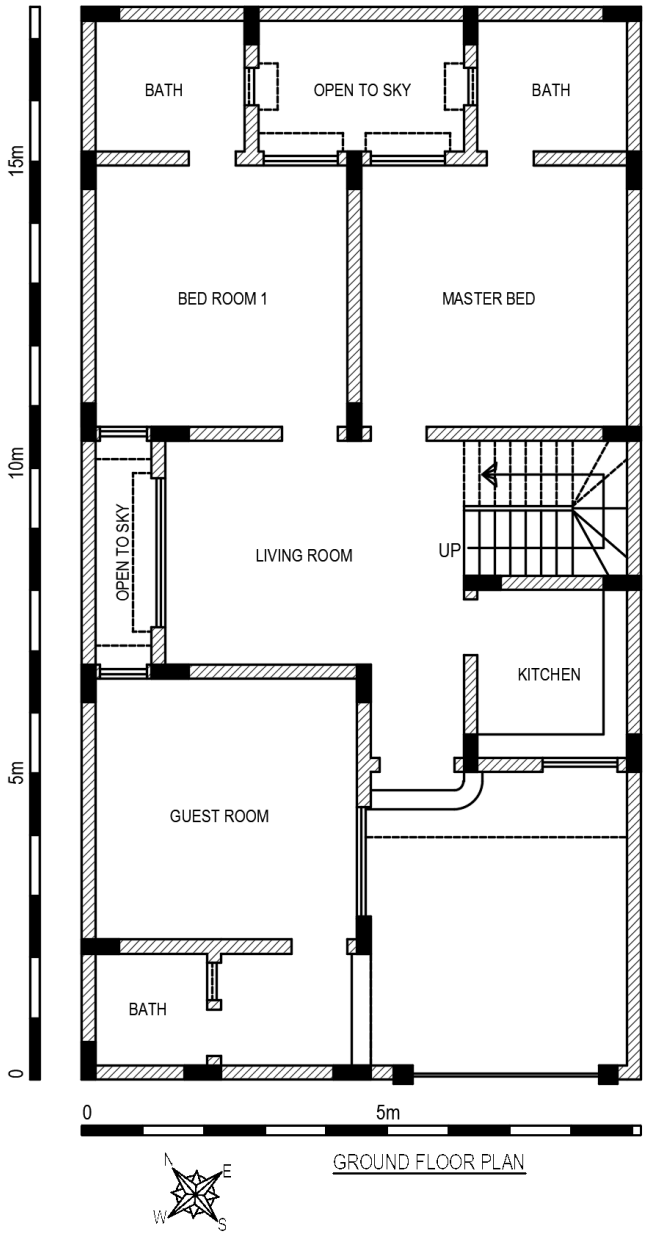

Figure 15 Ground Floor Plan of House VI

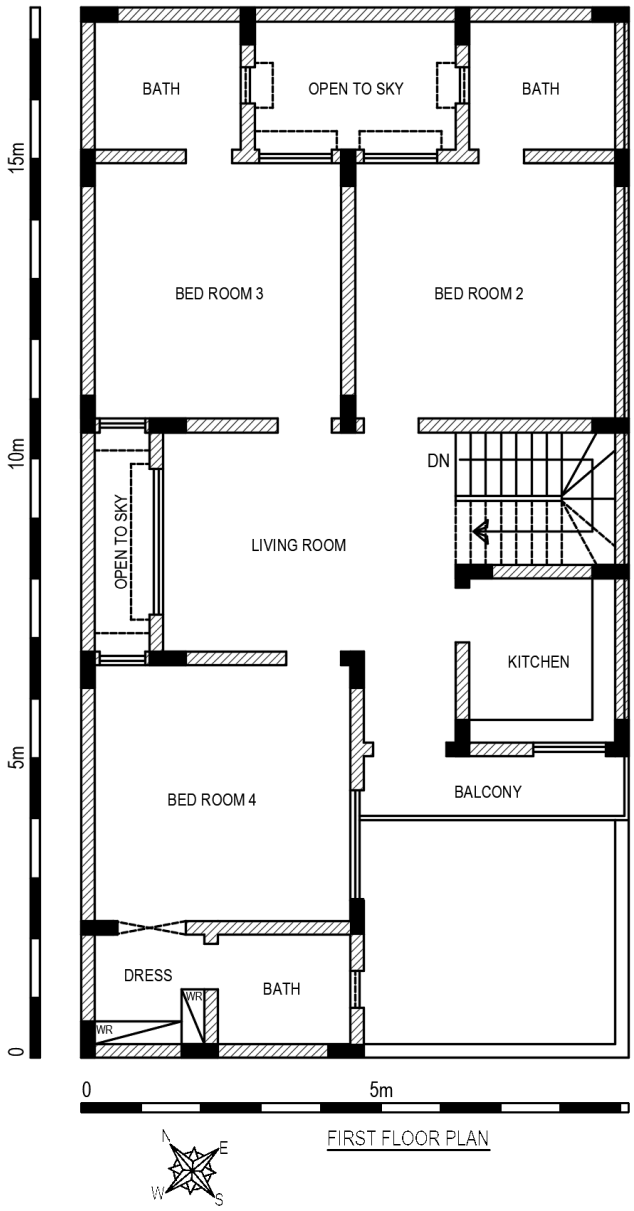

Figure 16 First Floor Plan of House VI

3.1.6.1 HVAC systems, energy & lighting

Two bedrooms and one living room are mostly heated in this house. Some family members spend few days a month in this house and rest in a house at village. 6 members of the family permanently live in this house. All heaters used in this house are radiant gas heaters. Heating is mostly used between December to February and 8-12h per day. Heating hours are

mainly between 7h-10h in morning and 15h-23h in the evening. Heaters are turned off in night before going to bed.

There are ceiling fans in all rooms and there are 2 air conditioners in this house. Both ACs are on around 8-12h per day in summer during afternoon, evening and night. The rooms at first floor are colder in winter and warmer in summer compared to the rooms at ground floor.

There is a water boiler for hot water. It mostly remains off in summer between May-July. In summer, hot water is sometimes used for shower in cold morning and for washing clothes. Paid energy bills are not always kept for the record. The residents are not satisfied with the energy prices and mentioned that the gas bill in winter is always high. Cooking in done on natural gas and microwave is used for heating the meals.

There is 2h outage of electricity in winter and 4h in summer. In other areas minimum load shedding in summer is 6h and in winter it is 4h. Load shedding hours are fixed, and residents perform their daily tasks considering the outage hours. The house is powered by UPS system backed with rechargeable batteries to provide electricity during outage hours. Rechargeable LED lamps and lights are used in case of long electricity breakdowns to light the rooms in evening or night. The residents are unaware of the energy prices. They said the billing system differs according to total consumed kWh of the electricity, if you consume less the tariff is low and if you consume more the tariff is high.

Low gas pressure occurs in winter mostly in December and January. Heaters in rooms are turned off to cook meals during low gas pressure.

Some family members stay home during day hours. Two rooms, kitchen and living room are used in this time. Heating or cooling devices remain on depending on the season, for example, fans are used in both rooms in summer and heaters are on in winter. CFL and FL lights are used for lighting the house. FL lights are mostly on and preferred.

The lights were changed from incandescent bulbs to CFL and FL lights. There were dark coloured wall papers on the walls which makes rooms darker. Those wall papers were removed, and walls were painted with light colour to make the rooms brighter. There was fabric on the ceiling which was removed, and ceiling was painted with light colour. The residents are willing to do energy renovation, yet they are unaware of the available methods and techniques. The affordability of the materials and renovation is not a problem for them, yet they are concerned about the availability and the performance of materials for energy renovations. They prefer the durability and built quality of existing materials.

3.1.6.2 Behavioural insights

While some spaces of the house are not in use the lights and fans are turned off. Living room at first floor is mostly in use. If leaving home for few hours the refrigerator and the lights in courtyard and outside of the house remain on. Water boiler and refrigerator stays on even if whole family is away for few days.

Lights in the kitchen and rooms are turned on during day time as there is no proper natural light access in the house. One person in the house always leaves the lights and fans on while going out of the room or space.

Heaters stays on in winter even if there is no one in the room. Heaters are also turned on 1h before using the rooms or spaces. TV is turned off in night while mobile phone chargers stay connected. Natural ventilation is preferred but it is not enough to feel comfortable in summer so fans and ACs are turned on.

Windows are open in evening during summer and remain closed during day to avoid warm air enter in rooms. Windows are closed to stop dust and remain closed in winter to stop cold air.

3.1.6.3 Comfort and clothing

The living room feels comfortable when the heater is on. It is not possible to sit in without heater on in winter. In summer, the living room at ground floor is more comfortable and the one at first floor feels warm and suffocated. In winter, the bedrooms feel very cold if the heating is off. The same room feels hot in summer and for that AC remains on. If there is no electricity for long hours, it is not possible to sleep inside the room.

The existing ventilation, cooling and heating arrangements are satisfactory for the residents of this house. However, they would prefer convector gas heaters which remain on during the night to maintain the indoor temperature at a certain level.

According to the residents, the house is not well designed, and it gets very cold and hot. In winter, if someone is sitting little far from the heaters then feel cold. Sometimes one facing toward the heater and feel their back is cold. One person in the house, aged 30yo feel colder and hotter and always mention or complaint about discomfort. ACs are usually set on 20-22 degrees Celsius but the above-mentioned family member prefer temperature between 16-18 degrees Celsius. Same person also wears cap or muffler while sitting inside the house in winter.

The living room feel more unformattable in summer if it is full of the people and feel comfortable in winter in similar situation. Living room is mainly used for eating, sitting and watching TV. There is corner for ironing the clothes. It feels hotter in summer while pressing the clothes. In winter, female wear socks and Shawl even inside the house and male wear sweaters and Shawl while sitting inside the house.

Men wear warm clothes such as Khadi with dark colours in winter and cotton and light-coloured clothing in summer. Women prefer woollen clothes with Shawl in winter and light clothes such as cotton in summer with dupatta.

3.1.6.4 Renewable energy

The residents have enough knowledge about renewable energy systems and are using solar energy in their village house in Loralai district. They said, in villages the load shedding hours are longer so solar energy is a good solution. The household is also willing to install solar system in the exiting house in future and is considering to power air-conditioners on solar energy. According to them energy crisis in Pakistan can be solved by using coal and water to produce cheap electricity. In solar technology, they prefer grid connected supply system if the distances are not long else individually powered solar units.

3.1.7 House VII

The house is located in the neighbourhood of Killi Deba at Arbab Barkat Ali road near Joint road Quetta. It has covered area of 130 m^2 and there are 6 family members in the house which includes joint family of parents and their 2 sons (one married son his wife and child and one unmarried son). The house was constructed in 2004 and it is single storey house. The thickness of exterior and interior walls is 9" or 22.86 cm. The plan of house is shown in Figure 17.

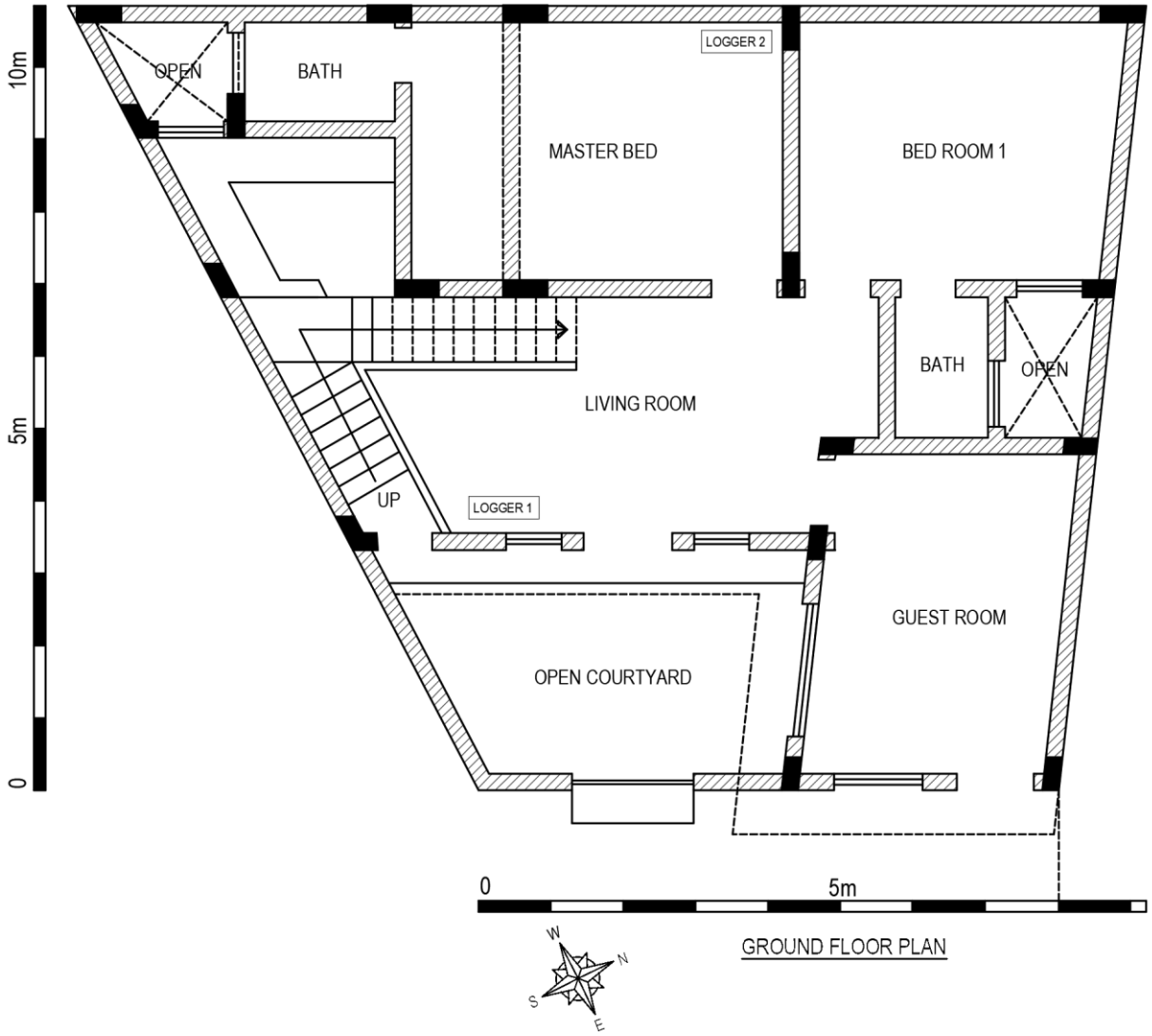

Figure 17 Ground Floor Plan of House VII

3.1.7.1 HVAC systems, energy & lighting

All three rooms and the living room are heated in winter. There are 4 heaters in the house and all are radiant gas heaters. On average the rooms are heated for 10-12 h per day.

All rooms are ventilated in summer. There are ceiling fans in all rooms. Fans are on 8-12h per day in summer days. Living room is not used between 10h-13h so that fan and lights in living room stays off during this time.

Water boiler is used for domestic hot water. The boiler remains on during summer. Old energy bills are kept for personal record. The residents are fairly satisfied with the energy prices. However, they don't know the billing system for energy prices. Cooking is done using natural gas and there is a microwave to heat the food.

The neighbourhood receive severe load shedding in summer. Usually there is 2h load shedding after every 1 hours in summer months. The situation also remains worst in winter. Load shedding hours are fixed, yet extra hours of load shedding occur in this area. Rechargeable LED lights are used during outage hours in evening or night. However, there is no provision of ventilation except opening the windows for natural ventilation. There is also a gas lamp which is not used in recent years.

Gas pressure drops in winter specially in January and February between 20h-1h midnight. In such situation the heaters are turned off to have enough gas for cooking meals. The residents put on warm clothes to heat up their body while the heaters are off. LPG cylinder is used for cooking meals in case of very low pressure or outage of gas.

Two females and the child stay home during day hours. Kitchen and living room are mostly in use during this time. CFL and FL are available for lighting the house whereas CFL are mainly used.

Floors are carpeted in winter to avoid the cold since the floors are mainly finished with marble and tiles. According to the residents due to the orientation of the house even after doing energy renovation the house may not perform well. However, they are willing to use insulation and do energy renovation if it is affordable for them. They consider cost, better finish quality and durability of the materials rather than energy performance.

3.1.7.2 Behavioural insights

Lights and fans in bedrooms are mostly off during the day and turned on around 18h in summer while in winter lights are turned on between 16-17h. In summer, fans in rooms remain continuously on from 18h in the evening till next day morning. Extra lights are turned off and someone in the house takes care of it.

While leaving house for few hours refrigerator and the lights in living room and courtyard remain on. Someone always stays home during holidays and use only living room and one bedroom. House is never left empty due to security reasons. The neighbourhood do not have good reputation and house stealing occur if no one stays in the house overnight. One room in the house need more heating and cooling compared to others. The house doesn't have enough day light, so lights are turned on in kitchen and lounge to perform daily work.

The heaters remain on even if the rooms are not in use. During cold season heater in living room always stays on during day hours except when there is no one in the house. Heaters in rooms stay on even if the rooms are not in use for 2-3h. All heaters are turned off at night before going to bed.

The house does not have proper ventilation and it feels very uncomfortable to sit in without turning on fans. In summer, all family members sit in the living room and open the windows during load shedding hours. Windows are opened in summer specially the windows of living room and only closed if there is dust coming in. In winter all windows remain closed.

3.1.7.3 Comfort and clothing

The living room feels very cold in winter, there is only one heater and it is not enough compared to the size of the room. In summer, the same living room feels moderate while windows are open, and fan is on. The bedroom is very cold in winter, there is a glass window and it is single glazed while in summer just turning on the fan is enough to achieve moderate comfort in bedrooms.

The residents are fairly satisfied with the existing facilities of heating and cooling in the house considering their financial situation. However, they said that turning on heating at full speed can make the rooms warm and uncomfortable and turning off them make rooms colder. Since the heaters are radiant gas heater, turning it on for long hours creates suffocated environment in the rooms.

In winter, men wear warm clothes and jeans. They mostly wear Shawl while in the house and put on sweaters while sitting and awake and only remove before going to bed. In summer, wear clothes made of cotton, t-shirts, and shorts. Women wear warm clothes in winter and keep sweaters while in the house. In summer, clothes made of cotton or lawn are used.

4.1.7.4 Renewable energy

The residents are aware of solar energy and its benefits but not considering it due to its high initial cost. According to them renewable energy can play a vital role to eradicate the energy crisis of Pakistan. They prefer grid connected solar systems rather than individual systems for each household.

3.1.8 House VIII

The house is situated in Gulf Colony which is a planned housing scheme with gated community at Quarry road, Quetta. The covered area of the house is 130 m^2. The household size is 7 members including parents, their 3 kids and one uncle. However, mostly one nuclear family stays in the home. The house was built in 2007. The walls have a thickness of 9" or 22.86 cm. The plans of house are shown in Figure 18.

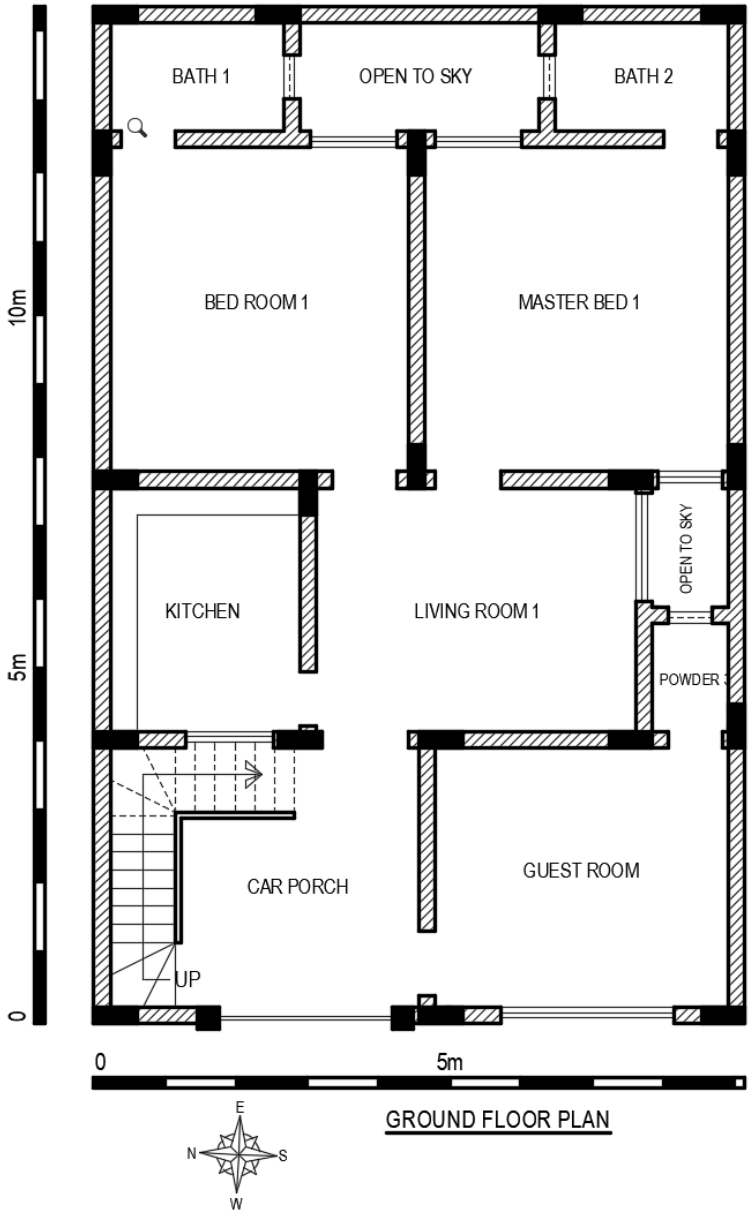

Figure 18 Ground Floor Plan of House VIII

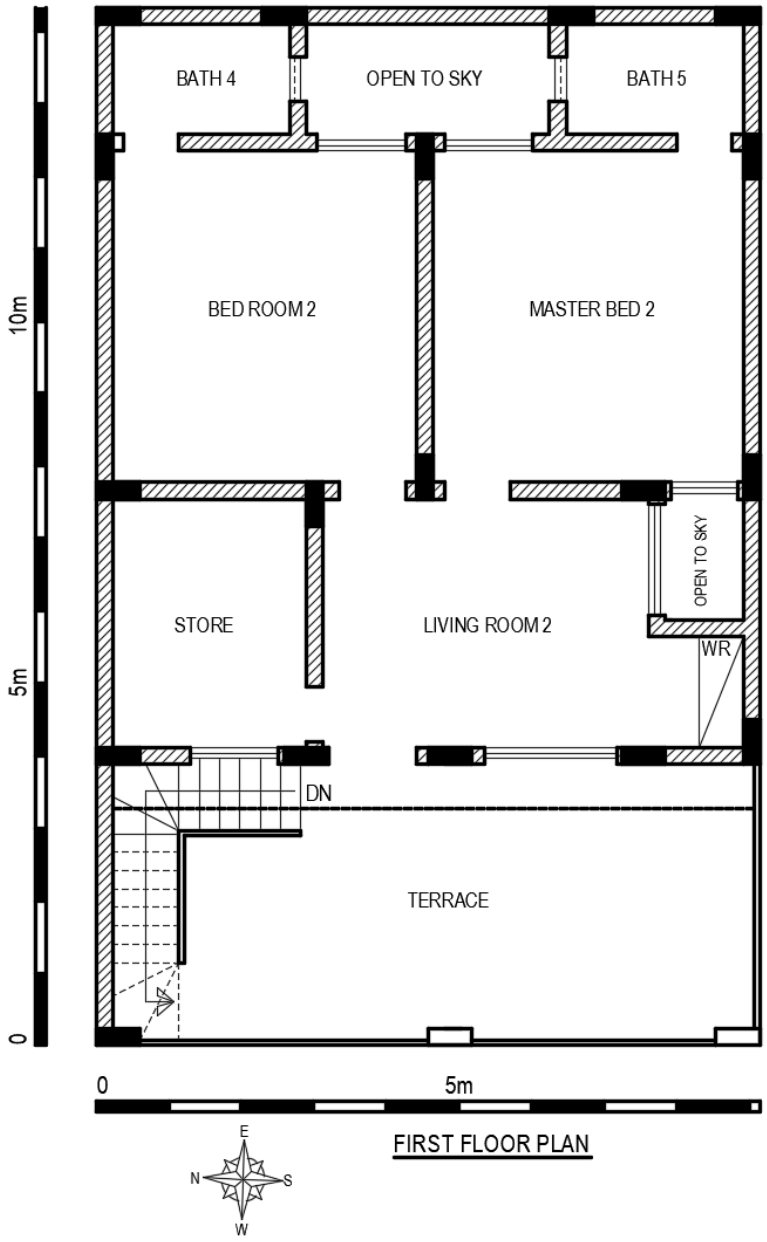

Figure 19 First Floor Plan of House VIII

3.1.8.1 HVAC systems, energy & lighting

There are 3 heaters in the house. Two in bedrooms and one in living room. All heaters are radiant gas heaters. The heaters are used 7-10h per day. 1-2h in morning and 5-7h in the evening.

Ceiling fans are fixed in all rooms and there is one air conditioner in the house which is not always used. Fans in rooms are used 2-3h per day in afternoon and from evening to next morning. On average fans are used 12-15h per day. The rooms at first floor are hotter in summer while more heating is needed in all rooms in winter.

There is one water heater and is used throughout the year. Hot water is rarely used for shower in summer, but it is used for doing dishes and washing clothes. Old energy bills are kept safely. The tenants don't know the energy prices of one m^3 of gas or one kWh of electricity. They are fairly satisfied with the electricity prices and very satisfied with the gas prices. They think gas bill in winter is according to their consumption. The average gas bill of the house in winter is between Rs. 6-9 thousand. Natural gas is used for cooking meals and there is a microwave oven which is mainly used to heat food.

This area receives 4h per day load shedding in winter which increases in summer from 5h to 6h per day. Often there is load shedding out of specified hours which is more serious between the months of April-October. Rechargeable LED lights are used during load shedding hours to light the rooms in evening or at night. There is an old gas lamp, but it is no more in use. The residents do not own any generator or other system to power the house during load shedding.

Gas pressure is low in winter months of Dec, Jan and Feb mostly in evening between 18h-00h. The heaters are turned off to finish cooking during such situation. There is also a LPG cylinder in the house which is using for cooking during very low gas pressure or in case of outage of natural gas.

One person stays home during the day and use kitchen and living room. There are CFL and FL lights in the house while CFL lights are mainly used.

Lime is applied on the roof of first floor to reduce the sun exposure. Piece of carpet is fixed on the lower part of the doors to block dust and air. Carpets are put on the floors to avoid cold floors. The windows are not air and water tight and during heavy rains some water enter in the house from windows. Towels are usually placed at the sill level to absorb such water and avoid wet floor. The family is willing to perform energy renovations in the house to make their house more comfortable. Their concerns are cost and the practicality of the available methods and solutions.

3.1.8.2 Behavioural insights

The residents try to turn off extra lights and fans. Yet, one person in house takes more care than the rest. All heaters are turned off before going to bed in night. Once a heater was left on and a few things got burned but luckily there was no major damages. During low gas pressures the heaters in bedrooms are turned off and the one in living room remain on. The doors of bedrooms are opened so that the heat flows from living room to the bedrooms.

In summer, during load shedding hours all family members prefer to sit in living room and open the windows and doors. Living room feels comfortable than the bedrooms. The house is not well-designed to get maximum benefit of natural ventilation. The windows are kept open in summer mostly in the evening and remain closed in winter. Windows are also closed to avoid entry of dust particles in the rooms.

If all family members go out for few hours the lights in living room and outside remain on. Refrigerator and water boiler remain on if the family leaves the house for few days. Lights are turned on during day time in kitchen and sometime in the rooms at ground floor. The residents said that the room at first floor receive enough day light.

3.1.8.3 Comfort and clothing

The living room feels very cold during winter as it receives no direct sunlight during the day. The same living room feels comfortable in summer by just turning on the fan. The bedrooms feel very cold in winter and very hot in summer specially the ones located at first floor of the house. Since the rooms at first floor receive more sunlight through roof and walls yet remain warm than the rooms at ground floor.

The household is fairly satisfied from the ventilation and heating devices used in the house, mentioning that the house is not comfortable if there is no ventilation and heating. That means turning off fan and heaters can make the indoor spaces really uncomfortable.

The men wear clothes made of warm fabric such as Khadi in winter and light fabric in summer. While sleeping they prefer Banyan (vest) and Shalwar in both seasons. They also wear Shawl while sitting in the house in winter. In winter, women keep worn sweaters in the house while performing their domestic work

3.1.8.4 Renewable energy

Renewable energy and its use are not new to the residents of this house. They have seen use of solar PV in the rural areas and villages of Balochistan. In their village home, they use solar PV for electricity since the load shedding hours are long in rural areas. They also use solar powered fans and air coolers as well. The family is willing to use renewable energy technologies yet their concern in urban areas is lack of solar exposure in most of the houses and initial expenses to install the solar system. According to them renewable energy can be very useful in Pakistan, yet it is one of the most ignored methods of energy in the country. In the city life they prefer conventional methods and solutions and in rural areas solar energy including solar water heaters and solar powered tube wells.

3.1.9 House IX

This house is located in employee housing of Balochistan University of Information Technology, Engineering & Management Sciences (BUITEMS) Takatu campus. It is one of the officer's bungalow comprising the covered area of 140 m^2 and it is single storey house. Six family members live in the house including 3 kids and 3 adults. The house was planned and built by Pakistan Public Works Department (Pak PWD) during 1970s. The house was renovated various times and recently it went through extensive renovation in 2016. The wall thickness is 13.5" or 34.29 cm. The plan of house is can be seen in figure 19.

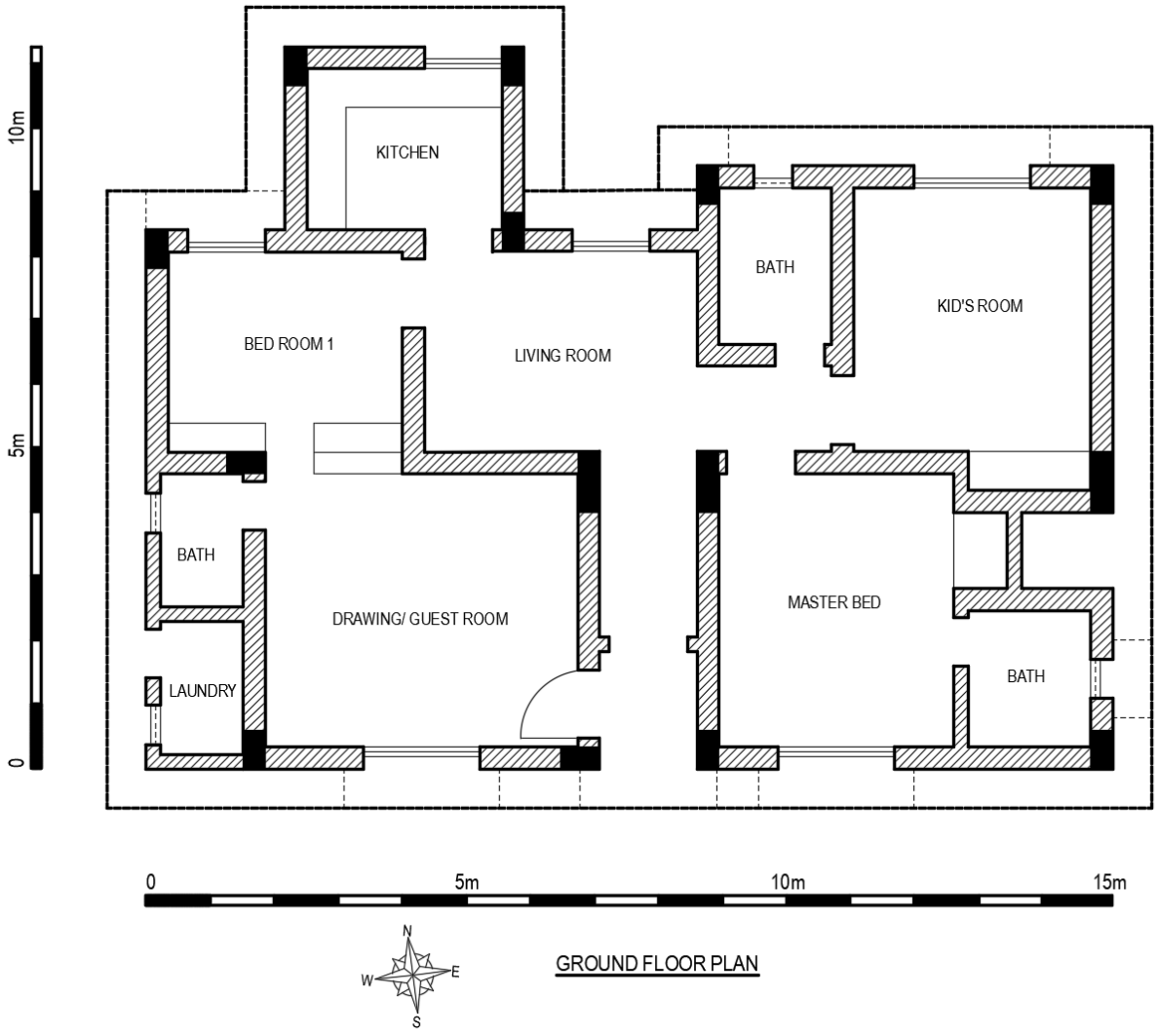

Figure 20 Ground Floor Plan of House IX

3.1.9.1 HVAC systems, energy & lighting

There are 4 heaters in the house. Three of them are used in two bedrooms and in living room. One heater is in guest room and is used when there is some visitor in the house. The heaters in bedrooms are gas convector heaters and the ones in living and guest rooms are radiant gas heater. On average the heating is on for 12hrs in living room and 6-8h in bedrooms. During cold nights the heaters in bedrooms remain on whole night.

All rooms are equipped with newly placed ceiling fans. There is one air cooler as well in kids' room. In summer, both ceiling fans and air cooler are used during sleeping hours in afternoon and night. The fan in living room stays on most of the time and rest are turned on while room is in use.

There are two water boilers in the house. Both have thermostat and safety valves. The boilers remain on in summer and hot water is used for shower in cold morning during summer. The electricity bill is deducted by the university and gas bills are directly received and paid. The family is not aware of energy billing and pricing. They do remember how much gas bill they paid last time. The tenants are slightly dissatisfied from the electricity prices and very dissatisfied with the gas prices. According to them, they replaced two gas radiant heaters with convector gas heaters, yet the gas bills remain high. The average gas bill in winter is Rs. 13k-16k per month. Cooking is done by using natural gas and there is a microwave in the house to warm the food. Vacuum cleaner is used around 30min per day, 5 days a week to clean the house.

Luckily there is no load shedding since the university have dedicated power grid station to supply interrupted electricity 24x7. The site was previously a textile mill so dedicated electricity grid station was built to supply electricity to the factory. Same grid is still in use for the university nowadays. While other areas of the city face load shedding on average 4-6h per day in winter and 6-8h in summer there is no load shedding in the university and its residential area. There may be power-cuts for maintenance, but these are very short and infrequent. Mobile light or rechargeable lights are used in such time. The gas supply is adequate

throughout the year and low gas pressures rarely occur in winter, yet it is not very serious and happen occasionally. The household don't own an LPG cylinder.

All lights in the house are replaced with LEDs lights and all fans in the house got energy saving label. Two gas radiant heaters are replaced with gas convector heaters. Nippon Flexi Seal is applied on roof and false ceiling to avoid heat gain. Carpets are used to cover the cold floor in winter. Sealant are put on the windows to stop air leakages. The family mentioned that they have tried their level best to improve the energy efficiency of the house. They would only prefer energy renovation if there is cost benefit analysis. Use of alternative materials will only be preferred if there is no compromise on finish quality of the materials.

3.1.9.2 Behavioural insights

One family member in house take care of extra lights and devices and turn them off to save on bills. The light of living room and courtyard stays on while leaving the house for few hours. In case the family is leaving out for few days then water boilers are turned off, refrigerator and lights in courtyard stays on. In day time lights are only turned on in kitchen or if needed in other parts of the house. It depends purely on the activity. For example, while watching TV in day time the lights remain off.

If rooms are not in use the heaters are turned off. The heater in living room mainly remain on. Windows are only opened if there is someone in the bedrooms while windows in living room remain open during summer. In winter all windows are sealed by using thick cloth and using plastic to cover them.

3.1.9.3 Comfort and clothing

The living room of house feels slightly cold in winter and reasonably comfortable in summer. The roof is treated by Nippon Flexi Seal and there is false ceiling to control the heat gain from the roof. Yet, windows are opened in the evening and fan remain on. In winter, heater must be on in the living room. The bedrooms feel slightly cold and heaters in bedrooms

are kept on during the cold nights. In summer, the bedrooms feel slightly warm and windows are kept open to feel comfortable while sleeping. Guest room is warmer than other rooms maybe due to the heat of refrigerator. The residents are fairly satisfied with the ventilation and heating arrangements in the house.

Men wears Shalwar Kameez in both seasons. In winter thick fabric such as Grace (a local brand). In summer, mixed and thin fabric. Kids wear Shalwar Kameez, jeans and shirts during winter. While in summer shorts, 3 quarter pants, jeans and t-shirts. Female wear woollen clothes in winter and lawn in summer.

4.1.9.4 Renewable energy

According to the residents the use of renewable energy sources is wide-spread in Balochistan, especially in rural areas. People are using solar PV with batteries to power their houses. Solar powered fans and air coolers are also available. In villages the load shedding hours are 16h-20h per day and solar is the only hope for those people. Most of the systems are cheaply available as arrive in Pakistan through informal ways. Solar system is expensive to install, and batteries are expensive too. Since there is no problem of load shedding in our house, we are not thinking about using renewable energy sources.

For Pakistan, grid connected solar plants should be installed in all cities to solve the energy crisis. These systems can be used permanently or to supply electricity during outage hours or in specific times such as during the day. Coastal areas of Balochistan and Quetta have good potential of wind energy and wind turbines should be used to get benefit of it. Solar cookers and solar heaters can be introduced to reduce the gas consumption.

3.1.10 House X

Similarly, to house IX, this house is also located in Balochistan University of Information Technology, Engineering & Management Sciences (BUITEMS) Takatu campus Quetta. It is one of the staff's houses which were originally built for the mill workers and staff. The covered area of house is 63 m^2 and it is single storey house. A nuclear family live in this house including parents and their 5 kids. The current tenants renovated the house in 2017. Plan of the house is shown in figure 20. The thickness of walls of this house is 9" or 22.86 cm.

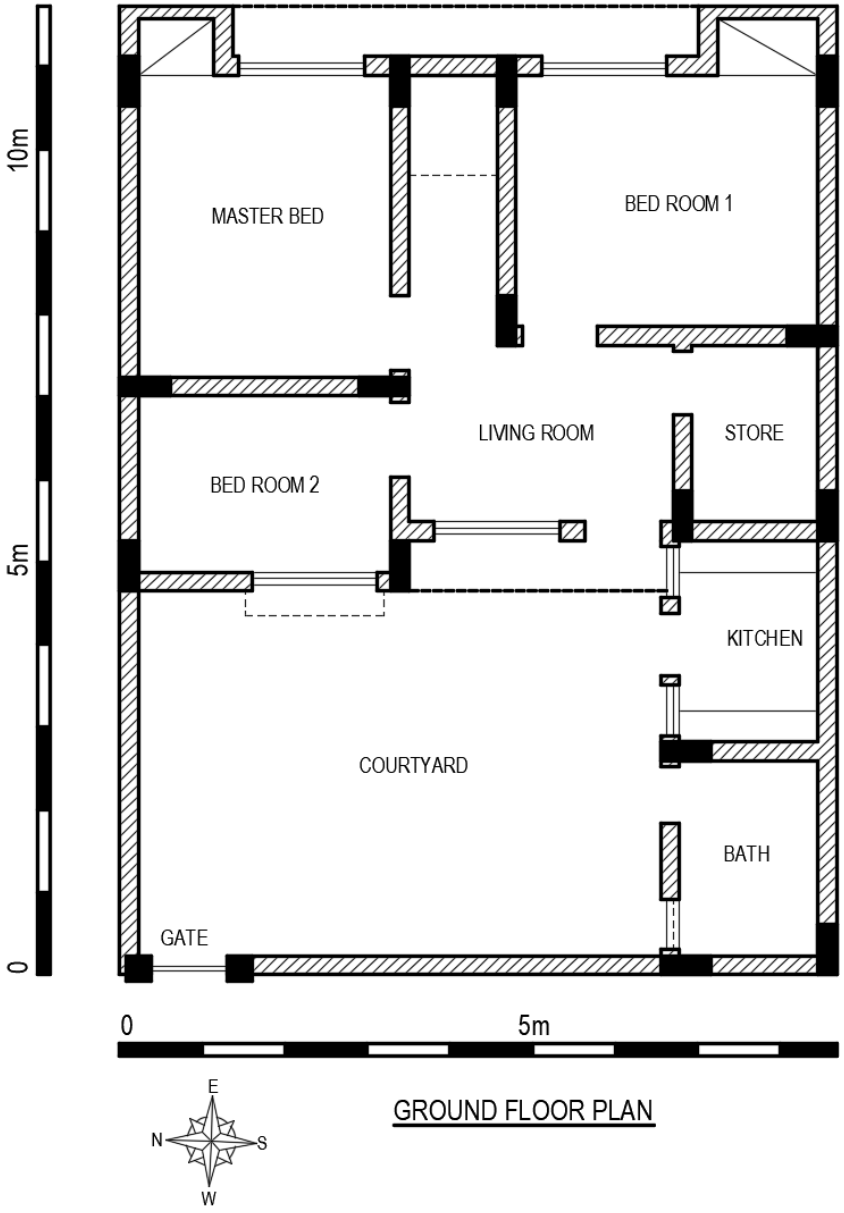

Figure 21 Ground Floor Plan of House X

3.1.10.1 HVAC systems, energy & lighting

All rooms are heated in the house which includes three bedrooms and one living room. There are three convector gas heaters and one radiant gas heater in the house and later one is used in the living room. Heating is on for 8-10h per day in a typical cold day and 4-6h per day during mild cold. The convector heaters stay on during very cold nights while sleeping.

There are ceiling fans in all 3 bedrooms and a wall mounted bracket fan and air cooler in the living room. Air cooler is mostly on in summer and turned off 4-6h per day. There is a hot water boiler for the domestic hot water which remains on round the year. In summer, kids prefer to take shower with warm water and it is also used for doing dishes and laundry. The electricity bill is deducted by the university while gas bills are directly received and paid by the tenants. They are unaware of the energy billing and price system. They are slightly satisfied with the electricity and gas bills. Natural gas is main source of cooking, there is one microwave in the house to heat the meals and one gas oven for cooking and baking.

There is no load shedding. The gas pressure occasionally drops during cold evenings in January and February. The heaters remain on during low gas pressure.

One person stays home during the day. Kitchen living room and courtyard is mostly used in day time. Lights, heaters and fans remains off while the space is unoccupied. CFL and FL lights are used for lighting the house.

Lime is applied on the roof to control heat gain from the roof. Residents said they would like to do energy renovations if it is affordable.

3.1.10.2 Behavioural insights

Extra lights and devices are turned off. Parents mainly take care of it. While leaving home for few hours refrigerator and water heater stays on. All electric and gas appliances are

turned off leaving home for few days. During day time lights are turned on if needed, especially in one room. For example, lights are off while watching TV and turned on for cutting vegetables.

Windows are opened in summer during evening and night and only closed if there is dust in the atmosphere. The house feels very much uncomfortable if the windows are kept closed in summer. Windows remain closed in winter to avoid dust and cold air.

3.1.10.3 Comfort and clothing

The living room feels moderate to the adults while it feels very cold to the kids in winter. According to kids the living room is cold due to air infiltration. In summer, it feels very hot to the adults and slightly hot to the kids. They added that the existing bracket fan is not enough for the living room. A big ceiling fan is needed to provide proper ventilation in summer. A child said that if air cooler is on then its fine once it is off he feels living room is very hot.

The bedroom feels normal to the adults in winter and slightly hot in summer. The kids feel their room is very cold for in winter and one of the children mentioned that she wear 2-3 blankets during cold winter nights. The same room feels moderate in summer when fan is on and windows are open. One of the adult members of the house feel hotter than the rest no matter what the season is. The bedroom-1 is cold in winter, so heating stays on during night, yet they said it feels very hot in summer as there is no cross ventilation in the room.

The parents are very satisfied with the available ventilation and heating provisions in the house. While the children are slightly satisfied and said due to our current financial situation, we are not able to improve the ventilation system and put on air conditioning yet in winter we leave the convector gas heaters on to maintain the indoor temperature.

The living room need more cooling in summer and all rooms need more heating in winter. Rooms get very hot and cold without using fans and heaters.

Men wear cotton and wash n wear (mixed) type of clothes. Shalwar Kameez in both seasons. Using mixed fabric make them feel warmer in hot weather then they prefer the clothes made of cotton. The head of the house do not wear sweater or jackets in cold winter as he doesn't feel cold. Women wear clothes of velvet and thick fabric together with Shawl in winter. In summer lawn and linen. Male children wear pant, shirt, jeans, formal shirts or Shalwar Kameez with sweater or jacket or Shalwar Kameez during winter. In summer mostly jeans, t-shirts, shorts, 3-quarter pants or Shalwar Kameez with vest.

3.1.10.4 Renewable energy

The residents know little about renewable energy and especially Solar energy. They said, if it is possible and practical to operate our house on solar energy, then we will surely prefer it. If we can get some help or subsidy from the government then it would be great. Or if we would have money, we would prefer to invest in using solar PV for our house. They are confident that the solar or renewable energy can be a good solution for the energy crisis in Pakistan. They think the solar water heaters do perform well. If there is an opportunity in future they are willing to install a solar water heater to save on energy cost.

3.2 Monitoring data

The monitoring of indoor and outdoor climate was done for this study. Only air temperature and humidity were monitored for four weeks, two weeks each in summer and winter. The outdoor temperature and humidity measured during summer period is shown in Fig. 22, 23 while fig. 24 and 25 shows the outdoor temperature and humidity measured in winter period.

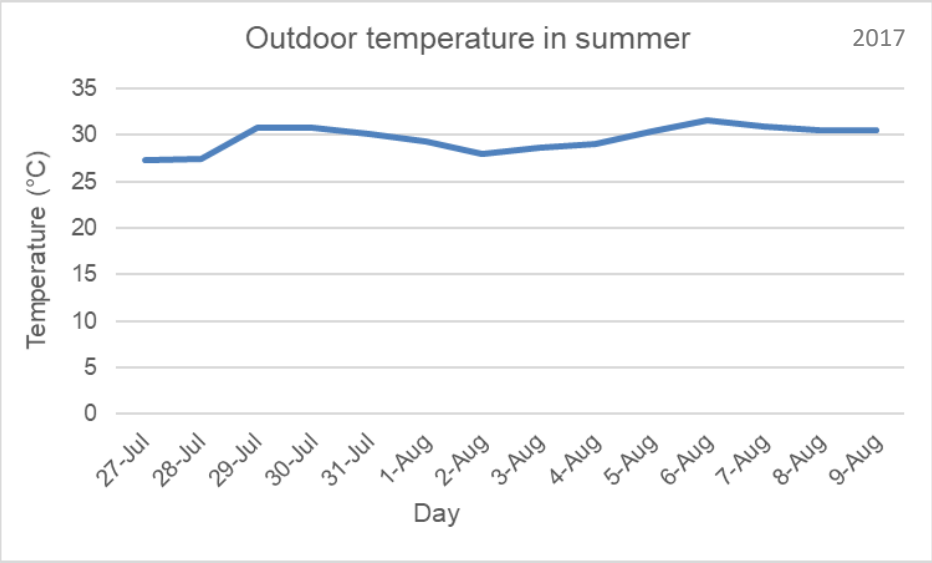

Figure 22 Outdoor temperature in summer

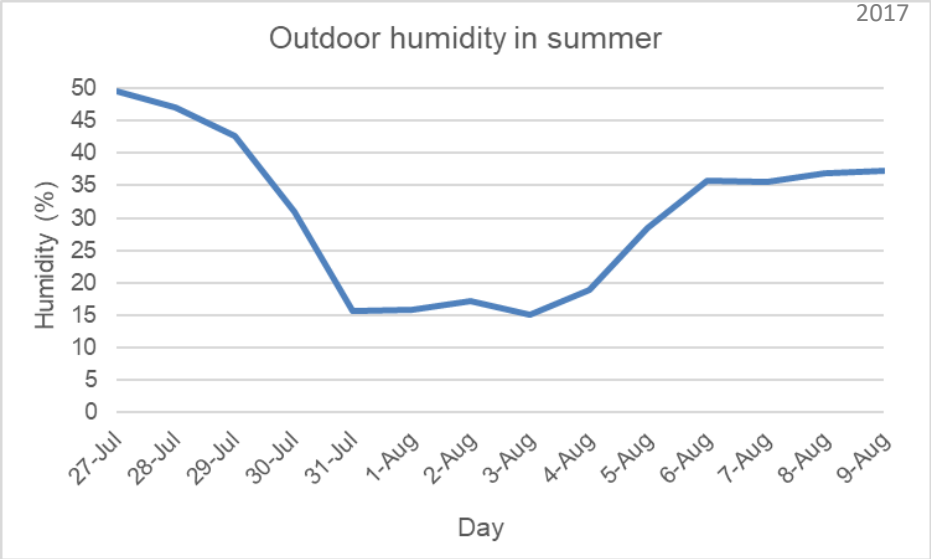

Figure 23 Outdoor humidity in summer

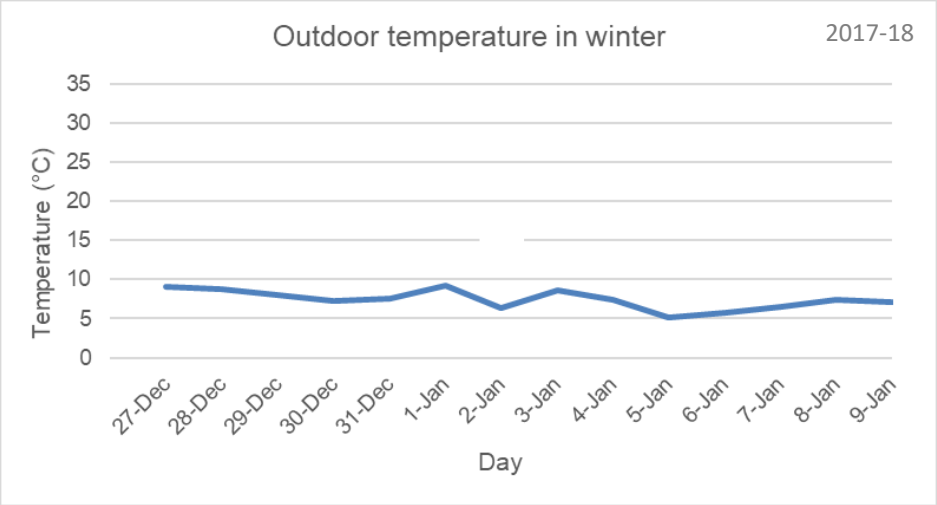

Figure 24 Outdoor temperature in winter

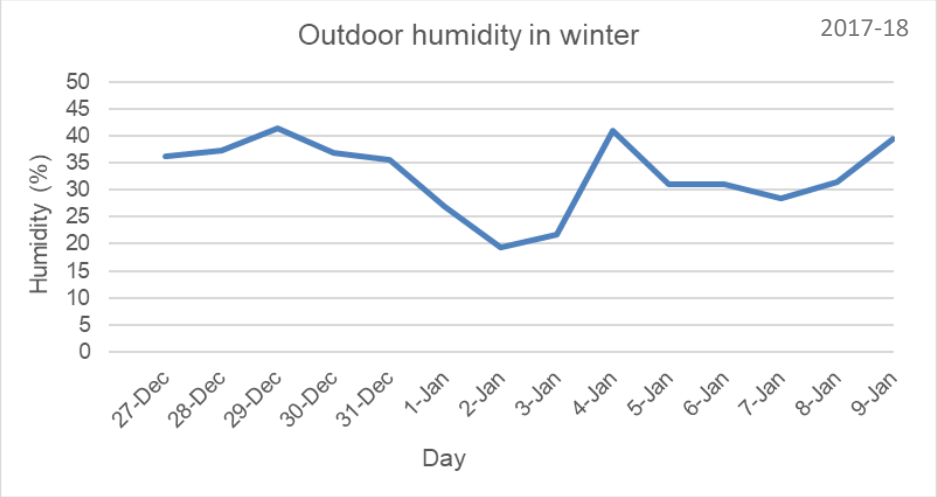

Figure 25 Outdoor humidity in winter

Fig. 22-25. Outdoor climate conditions (daily) during summer and winter

Fig. 23(a), 23(b), 23(c) and 23(d) presents the air temperature ℃) and humidity data measured in all 10 houses (living rooms only) during the monitoring periods in summer and winter. Typically, the indoor air temperature relies on outdoor air temperature. If the outdoor air temperature decreased, indoor air temperature decreases as well. Similarly, when outdoor air temperature increases the indoor temperature increases.

The variations in indoor air temperature were recorded in all ten houses in summer. There was a temperature variation between 29.5˚C to 34.4˚C during monitoring period which shows that indoor climate was very uncomfortable. In general, houses II, IV and VII remained warmer during most of the days while comparatively lower temperatures were recorded in house VI and IX.

In summer, the indoor humidity level remained lower as compare to winter. The variation in humidity level was between 15.5% to 43.5%. Humidity level in house IV and VII comparatively remained low while it was better in house VI and IX during summer monitoring period. It has been noticed that at higher temperature the humidity level decreases that's why the humidity level inside the houses in winter is better compared to humidity level in summer. In house II, the humidity level remained better in both summer and in winter and showed no relation with temperature differences. It might occur due to the presence of an underground water tank underneath the floor of the room.

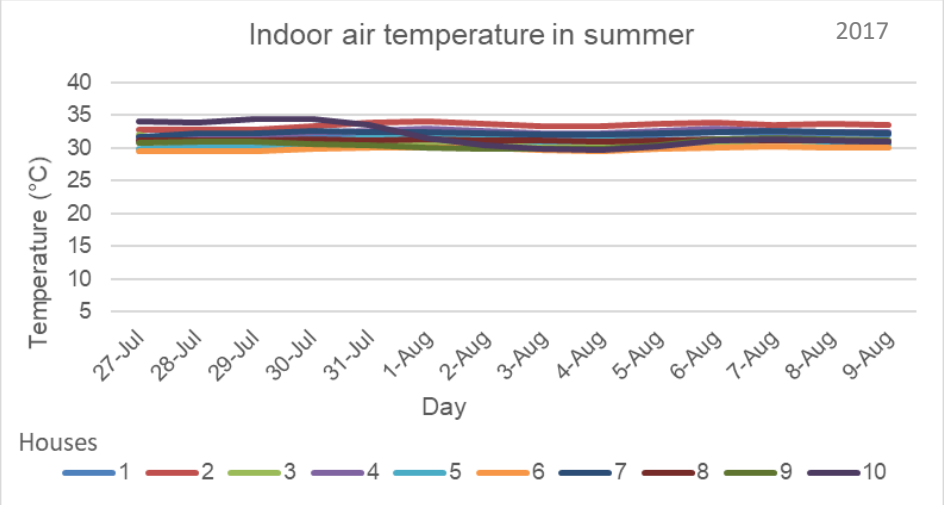

Figure 26 Indoor air temperature in summer

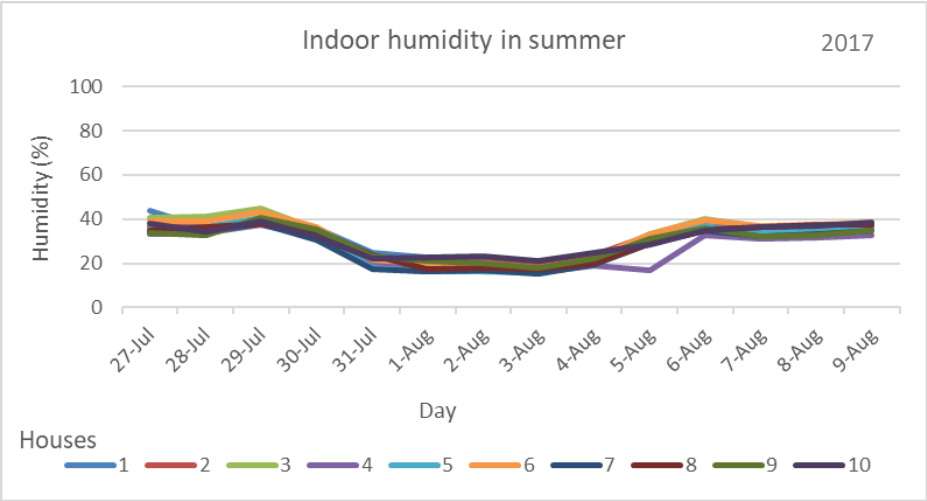

Figure 27 Indoor humidity in summer

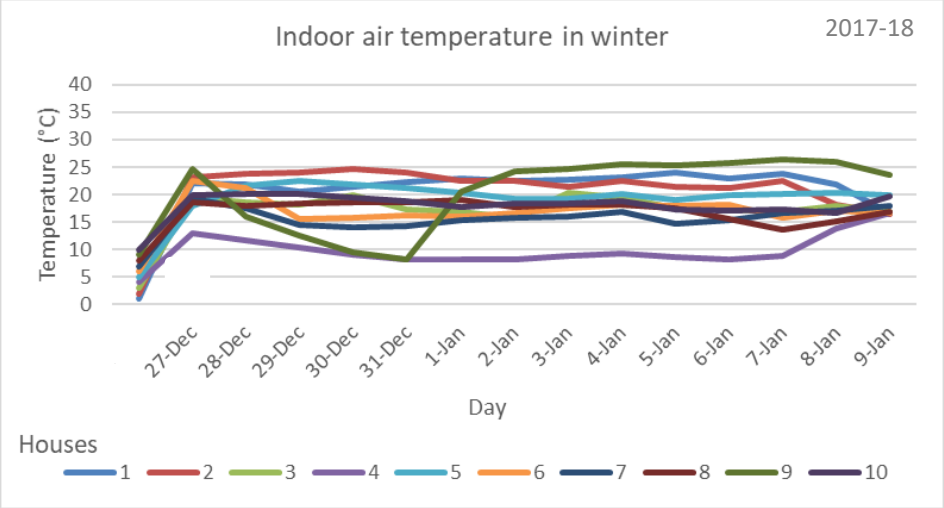

Figure 28 Indoor air temperature in winter

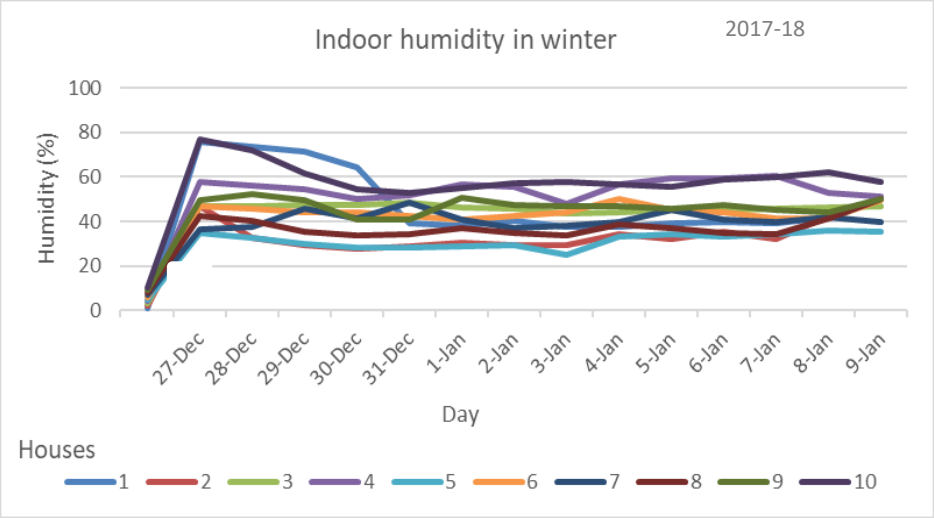

Figure 29 Indoor humidity in winter

Fig. 26-29. Indoor climate conditions during summer and winter

The significant variations were noticed between indoor temperature and humidity in winter and in summer. The variation of indoor temperature was between 8.1˚C to 26.3˚C during the monitored periods. Higher temperatures were observed in Houses II and V compared to the rest while in house IV lower temperatures were observed. The humidity level in winter varied from 25% to 76.9%. Higher humidity levels were recorded in houses I, IV and X while it remained low in houses V and VIII.

3.3 Control systems

Control systems enable occupants to modify the indoor climate as per their needs. Windows, ventilators and doors are used in naturally ventilated buildings to control the internal temperatures in buildings. While fans, evaporative coolers, air-conditioners and heaters are used in extreme conditions to maintain the indoor temperatures. These systems are important to get comfortable environment inside any building and are discussed in detail based on the responses of the occupants of the houses included in this study.

3.3.1 Windows

Openings such as windows and ventilators are important to control indoor climate in a house. Occupants open and close windows to get fresh air or maintain the indoor temperatures depending on the weather and seasons. It was noticed that window opening in Quetta not only depends on weather conditions and seasons but also on other factors such as avoiding dust particles, mosquitoes, flies as well as electricity outage and use of space. Windows are opened in majority of the houses in evening or nights of summer and remain closed in winter.

It is also a common practice in Quetta to seal the windows during winter to avoid cold air entering house due to air leakages from window frame/ fixing. For this purpose, first, a thick cloth/ fabric is fixed by nails over the surface area of the window (from outside) and then a plastic sheet is placed over the cloth and sealed by using masking tape. This plastic sheet protects the fabric from rain water and snow and blocks the entrance of air.

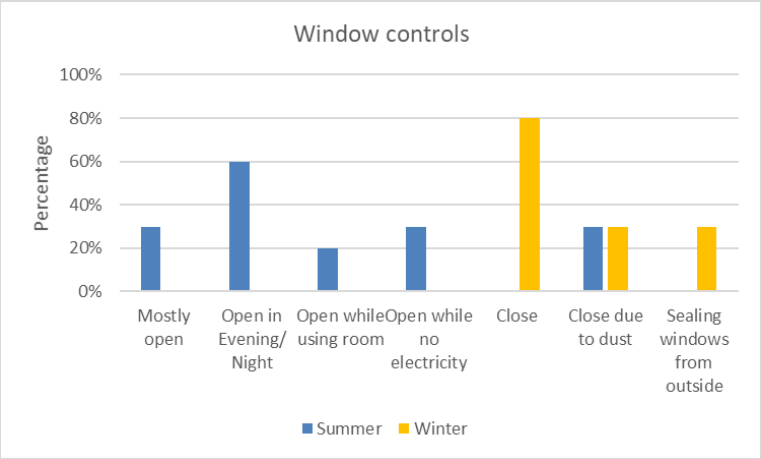

Figure 30 Window controls in summer and winter

3.3.2 Cooling

The climate of Quetta demands heating as well as cooling as there is significant temperature difference between summer and winter. Ceiling fans are commonly used in all buildings including houses to provide indoor comfort during occupancy hours in summer. Evaporative coolers which are locally known as air coolers are also used during hot summer months. The following table (Table *2*) presents the available cooling devices in all 10 houses selected for this study. It was found that all bed rooms, living and dining rooms were equipped with ceiling fans except in house X, where wall-mounted or bracket fan was used in living room. These ceiling fans are used between 8-12h per day during summer period depending on occupancy and weather conditions.

In some rooms exhaust fans are used to remove the warm air and continue the flow of fresh air. While these exhaust fans are used in kitchen and toilets to remove the smoke and smell. Evaporative or air coolers are used in the rooms or portions of the house which are warmer than rest of the rooms in the house. These air coolers are mainly fixed in a window and are used for 2-3 months during hot summer. Air-conditioners are used in the bed rooms of house III and VI during summer for 8-12h per day. However, air-conditioner in house VIII was not in-use even it was in working condition.

Table 2 Fans and cooling devices used in the houses

S. No.	Ceiling Fan	Bracket Fan	Pedestal Fan	Exhaust Fan	Air cooler (Evaporative)	Air conditioner
1.	All rooms	2	2	4	1	-
2.	All rooms	-	-	3	2	-
3.	All rooms	-	-	3	-	3
4.	All rooms	1	-	4	-	-
5.	All rooms	-	1	5	2	-
6.	All rooms	-	-	4	-	2
7.	All rooms	-	-	2	-	-
8.	All rooms	-	-	3	-	1
9.	All rooms	-	-	3	1	-
10.	3	1	-	1	1	-

3.3.3 Heating

During winter, the outdoor temperature in Quetta is much lower which tends to use indoor heating to get comfortable indoor temperature. The use of direct heating is a common practice in Quetta. Heaters are placed in each room or space of the house which are used between 6-12h per day depends on the occupancy of the residents and weather conditions.

Radiant gas heaters are commonly used in Quetta, see **Error! Reference source not f ound.**. Since these heaters follow the principle of combustion which increases the CO^2 level inside the rooms and affects the indoor air quality (IAQ). Usually a small portion of door or window is kept open for the fresh air and to avoid suffocation. The residents prefer radiant gas heaters since the per unit cost or price of gas heaters is lower than other types of heating devices.

On the other hand, the convector gas heaters (Figure *32*) use both gas and electricity and can not be operated during the electricity outage hours. Since there is 4-6h per day load-shedding or electricity outage in many parts of Quetta which also make it difficult to use gas convector heaters. However, the use of convector gas heaters is growing in recent years as these heaters are safer to use inside the houses. Considering the electricity outage hours in mind the residents keep both types of heaters in their houses and use radiant gas heaters to warm the indoor spaces in the event of no electricity. Both types of heaters were used in house IX and X to heat the indoor spaces. The convector gas heaters are kept on during the cold nights in order to maintain the comfortable indoor temperature.

Figure 31 Radiant gas heater

Figure 32 Convector gas heater

3.4 Clothing

Clothing is one of the important factors in thermal comfort studies. The occupants wear clothes according to the season and activity to adapt the comfort level. Clothing is also based on cultural and social aspects of the society. In this study the questions were asked about the

clothing of the occupants and the average clothing insulation values are calculated based on the responses. In winter, the average clothing insulation is 0.7 clo while it is 0.4 clo in summer. In summer, people mostly wear clothes with dynamic dimensions and loose-fitting and the clothing insulation of such clothes are only taken as indicative.

According to a previous study done in five different climate zones of Pakistan, the change about 3.5- 4 °C occurs in comfort temperature with a change of clothing insulation of 0.5 clo (Nicol et al., 1999).

3.5 Energy consumption behaviuor

It was found that the residents do complaint about the energy crisis and increasing energy prices while their energy consumption behaviour shows that only 1-2 persons in a house were really concerned about the overall energy consumption. Most of the family members, i.e. 67% out of 84 were not so cautious about the energy consumption and they leave the lights, heating and cooling devices on while leaving the rooms. Since the houses can get very cold so that in some houses the residents need to turn on the heating devices 1-2 hours before the use of any room during winter. Heaters also remain on if the rooms are not in use up to 2h during the day, as the rooms get cold very fast and take more time to get warm again. This shows that houses are not properly designed and are climate sensitive as the outdoor temperature increase or decreases it directly affects the comfort level inside the houses. This might occur due to lack of thermal mass, no insulations, improper design of house and air leakages etc.

3.6 Comfort perception

In order to understand the comfort level of the residents the questions were asked from all household members of 10 houses. The sample size is 84 which is the total population of the

selected ten houses. The responses of the residents regarding their comfort level in houses is presented in Figure 33. It is found that the existing houses do not provide optimal thermal comfort to the residents. The houses remain cold in winter and warm in summer which leads the occupants to use active heating and cooling systems in order to achieve comfortable indoor temperature.

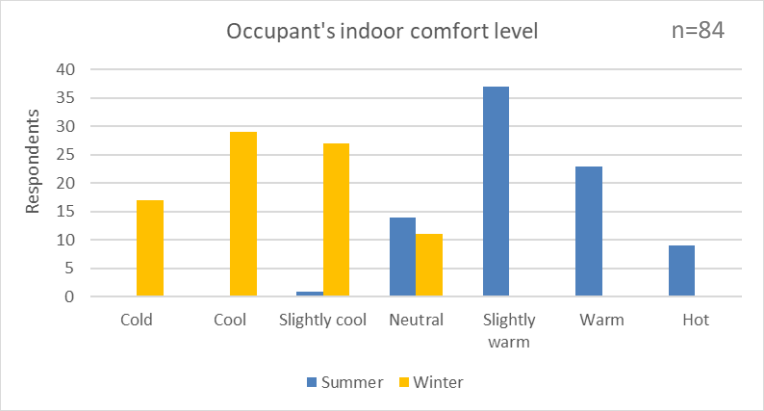

Figure 33 Indoor thermal comfort level of occupants

3.7 Energy

In recent years, the energy sector of Pakistan is going through major challenges and changes. Initially, the country was facing the problem of energy shortage and later there are problems of line losses, energy supply and distribution (Mahar et al., 2018). The existing distribution network is unable to supply enough energy as per the demand of the consumers. However, the energy sector of Pakistan heavily relies on the use of fossil fuels for the energy production and as of February 2018, only 2% of the total electricity is produced on renewable sources. While the share of thermal power was 64%, hydro power was 27% and nuclear power was 7% (Anwar et al., 2018).

Power sector remained the second largest consumer of oil during Financial Year (FY) 2016-17 by consuming 33% of the oil for electricity generation. On the other hand, between Jul

2017-Feb 2018, the power sector consumed 936 million cubic feet per day (MMCFD) of natural gas and remained the largest consumer of gas. Household sector remained second during the same period with the total consumption of 860 MMCFD of natural gas (PES, 2018). The use of fossil fuels for electricity generation increases the cost and energy prices and it is not environment friendly.

It was found that the use of solar energy is getting familiar in Balochistan and particularly in Quetta. In our survey, we found that house III and IV use solar panels backed by rechargeable batteries to fulfil the electricity demand of their household during electricity outage hours. The residents of other houses included in this study were also interested to use renewable energy sources, however, they prefer subsidy or reduction of initial cost for the installation of solar panels. There is a great potential in the province of Balochistan for the generation of renewable energy at various locations including Quetta. (NREL, 2007a) (NREL, 2007b).

According to our survey, the residents were less satisfied with the prices of electricity as compare to the prices of natural gas. The satisfaction of the residents from energy prices is shown in Figure 34. It is important to mention that the survey was conducted before the recent increase of electricity and gas prices in Pakistan after the general election 2018.

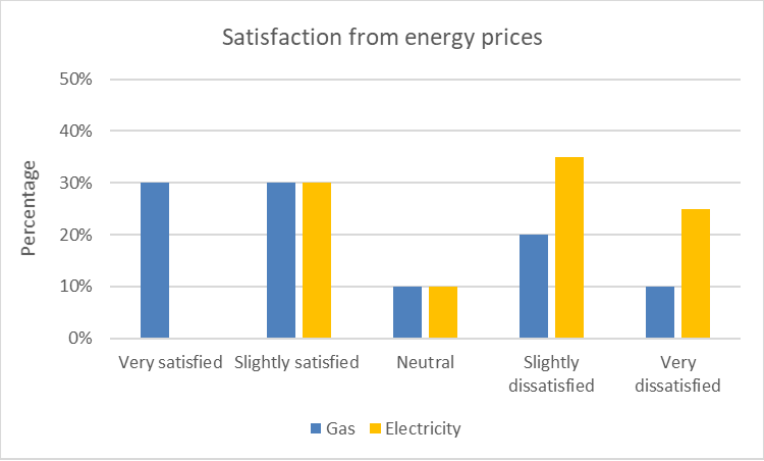

Figure 34 Occupants' Satisfaction from energy prices

4. Key findings

The key findings of this study are summarized as following:

- The houses in Quetta can be divided into detached and semi-detached. The first ones have their own boundary wall and the house is constructed inside the boundary walls. In the second one the house shares one or more common or attached side/ wall with another house.
- The existing RCC houses in Quetta do not provide optimal indoor thermal comfort to the residents and use of active systems is needed to achieve comfort in all selected houses.
- Fans and ventilators are commonly used in all houses while rich and well-versed families can afford and prefer air-conditioners.
- The houses are not insulated, and people have less or no knowledge about insulation techniques, materials and its benefits.
- Central heating and cooling system is not commonly used in Quetta.
- There are two types of heating devices usually used, radiant gas heaters and convector gas heaters.
- Exhaust fans are not only used in toilet and kitchen but also in bedrooms to draw out the warm air from inside the rooms.
- Residents are not very satisfied with the energy prices and billing system.
- Residents complaint about the high energy prices, yet no one really knows the details of pricing system. In such situation they cannot notice and take care of their actual consumption which might lead to high bills as well.
- The old ages and female members of the house feel colder or hot compared to young ones.
- To keep themselves warm and comfortable inside the houses some people wear Shawl, sweater or socks.
- Rooms at ground floor feel comfortable than the rooms at first floor in double storey houses.
- Not all houses are properly designed for ventilation and daylight

- Due to use of radiant gas heater the indoor air quality gets affected. It would be significant to find out the effects of combustion of gas for heating the rooms in winter and its effects on overall indoor air quality.
- Windows are also closed to avoid dust, mosquitoes and flies enter in the house.
- In some houses, windows are sealed from outside using thick fabric and plastic in winter to avoid the cold air.
- Incandescent bulbs are mostly replaced with compact fluorescent lights, fluorescent lights and with light-emitting diodes.
- Convector gas heaters are becoming more popular due to their compact, safe and user-friendly design and safe operation throughout the cold season.
- Load shedding throughout the year and low gas pressure in winter occur in many parts of the city. Residents use LPG cylinders to cook meals during extreme low gas pressure or outage of gas.
- The thickness of walls varies from 13.5”, 9” and 4.5” in different houses.
- Use of renewable energy technologies, especially solar PV is getting popular among the residents of Quetta.
- The construction materials used are not really climate friendly such as use of marble for floor finish.
- Carpets are commonly used to cover the cold floors.
- The residents are willing to do energy renovation, yet they do not get enough knowledge or guidance or help in this regard.

5. Conclusion

The study provides valuable insights about the climate of Quetta and its effect on indoor climate of the houses. The indoor temperature is usually dependant on outdoor temperature and follow the similar trends of increase and decrease in temperature. The selected free running RCC houses use active systems for cooling and heating in both seasons to achieve comfortable environment. This shows that houses are poorly designed and failed to deal with various range of temperatures. During higher temperature the humidity level decreases which causes more discomfort. It was observed that, in summer the air is mostly dry, and it contains dust particles. This dust causes several health problems and contaminates indoor spaces.

The energy crisis has badly affected the everyday life and people are looking for alternate and affordable measure to deal with this issue. However, renewable sources such as installation of solar PV is not affordable for most of the families. Residents are interested to install solar PV if they get some subsidy or reduction on initial cost. On the other hand, low gas pressure is a main problem in cold winter. Residents turn-off heaters during low gas pressure or use gas cylinders to cook their meals. The increasing fuel and energy prices is a big issue to be resolved. Yet, well-off families prefer to use air-conditioning and heating most of the time to achieve controlled environment and thermal comfort. Gas heaters used in indoor spaces increase the level of carbon which affect the indoor air quality. The residents are generally dissatisfied with the thermal comfort level and performance of the houses.

There is lack of legislation at provincial and local level regarding housing. The existing by-laws are not properly enforced in many parts of the city. People can build a house without get planning permission from the authority. The existing by-laws of Quetta Development Authority (QDA) have no energy provisions or considerations which should be included. Due to the high cost of land, resident try to construct on most of the plot area leaving very less and insufficient openings for natural light and ventilation.

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APPENDIXES

APPENDIX A

Questionnaire

The interviews were conducted from the residents of 10 houses. The following semi-structured questionnaire was used to collect the responses.

HVAC systems, energy & lighting

- How many rooms are heated in winter? Number types of heating devices? Heating hours? Source of heating.
- Ventilation and cooling system? Types and number of devices? Cooling hours per day etc.
- Satisfaction from heating and cooling systems in the house.
- Domestic water heating and use of hot water.
- Load shedding and low gas pressure problem. Cooking during outage of gas.
- Lighting and ventilation of rooms during load shedding.
- Types of lighting used in the house
- Any efforts taken to reduce the discomfort or reduce the energy consumption.
- User's satisfaction and knowledge about energy prices and billing system
- Opinion about energy renovation and use of alternative materials.

Behavioural insights

- Occupancy and living patterns
- Appliances in use during inoccupancy hours.
- Turning off extra lights or devices.
- Usage of heating and cooling devices and behaviour regarding keeping them on or off.
- Opening or closing windows and its causes.
- Keeping record of energy bills

Comfort and clothing

- Comfort feeling and perception of the residents in living rooms and bedrooms during both summer and winter seasons.
- Reasons of comfort or discomfort in living room and bedrooms.
- Portion(s) of the houses need more cooling or heating.
- Overall satisfaction from existing comfort situation in the house.
- Clothing used by men, women and kids in summer and in winter.

Renewable energy

- Knowledge and understanding of renewable energy.
- Preference and willingness to use renewable energy
- Factors involved in decision making, knowledge, cost, maintenance, lack of information.
- Energy crisis in Pakistan and possible role of renewable energy technologies to solve the energy problem
- Solar water heating

APPENDIX B

GLOSSARY OF THE TERMS

Qila (قلعہ): Qila is a word in Urdu which means Fort or fortified place. Bazai Qila is a huge multi-family residential compound at airport road Quetta with fortified mud wall. It belongs to a Pakhtun (Pathan) tribe names Bazai.

Drawing Room: A room typically used for the male guests of the house. It is also called Baithak (بیٹھک) in Urdu language. The room is associated for the guests who are not closed relatives or family members and who cannot be allowed to sit in the lounge (living room). This room is also used by the religious teacher or tutor to teach the kids.

Lounge: Lounge, also known as T.V lounge is the common name of living room in Pakistan. Lounge is used for the family guests or close friends who have access to the other family members of the house.

Geyser: Geyser is the common name used for water heater or water boiler in Pakistan. It could be electric or gas geyser.

Shalwar Kameez: It is the traditional outfit of the people in Indo-Pak subcontinent. It is generic term used for different styles of dress. The styles differ by gender yet Shalwar Kameez cab be worn by both male and female. The Kameez is 'a long shirt' and Shalwar 'a baggy trouser' are

two garments which are combined to form the Shalwar Kameez. It is also national dress of Pakistan (Nobleman, 2003) (West, 2009).

Dupatta: It is a Shawl like scarf, women wear around their head and shoulders. Dupatta is commonly used at part of women's Shalwar Kameez costume.

Charpai: It is a traditional woven bed commonly used in Indian subcontinent. The net of Charpai is made of cotton, natural fibres and date leaves.

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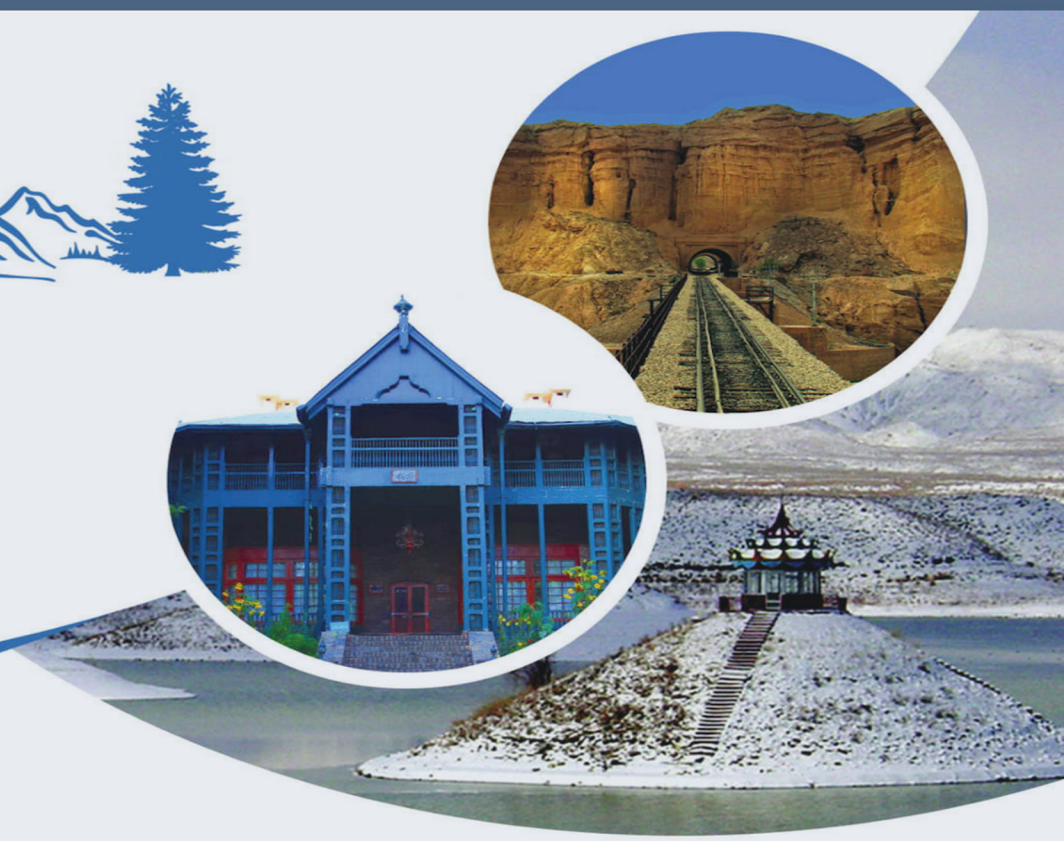
Waqas Ahmed Mahar is an architect and planner, graduated from Mehran University of Engineering & Technology (MUET) Jamshoro, Pakistan and he got his master's degree from Universiti Teknologi Malaysia (UTM) in Planning-Housing. He is Assistant Professor of Architecture at Balochistan University of Information Technology, Engineering & Management Sciences (BUITEMS) Quetta, Pakistan. Currently, Waqas works as a PhD researcher in the Sustainable Building Design (SBD) Lab at University of Liège. His research aims to develop a methodology for the design of climate responsive houses for optimized thermal comfort in Quetta, Pakistan.

Shady ATTIA

Shady Attia is an architectural engineer and professor of sustainable architecture and building technology at Liège University in Belgium. He is a faculty member of the United States Green Building Council and his area of expertise is high performance buildings (net zero energy buildings) and regenerative design. In 2014, he established the Sustainable Building Design (SBD) Lab. The lab is focused on identifying and evaluating efficiency measures, performance-based building design and monitoring techniques as a decision support methodology for building professionals.

Dr. Attia also works as an independent consultant in the area of buildings' energy efficiency and sustainability. As registered architect, and LEED accredited professional he worked with several governments for building efficiency programs as well as building design and energy consulting companies.



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