AN ASSESSMENT OF THE IMPACT OF IECC ON ELECTRICITY CONSUMPTION IN RESIDENTIAL BUILDINGS OF LAHORE, PAKISTAN

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Abstract

Energy consumption in residential sector is the highest among all sectors in Pakistan. Therefore Buildings Energy Conservation Codes (BECC) can serve as a strategy to ensure energy saving by designing energy efficient buildings. The objective of this research is to assess the impact of U-Value in international energy conservation codes (IECC) with regard to design of energy efficient residential buildings for middle income families in Lahore. The present research will also focus on developing an assessment process using these international standards as benchmark in order to address the local conditions set by climatic studies, and their application on the design requirements of the residential buildings. In order to assess the impact of IECC on the consumption of electricity in residential building for middle income families of Lahore, an existing house in Lahore was selected as a base case. A comparative analysis of the electricity consumption was done using the base case of commonly used envelope materials and three proposed cases of locally available materials which are closest possible to reference standards of IECC. The comparison of results shows that up to 39 % of electricity is possible to be saved by applying the standards as suggested in IECC. The results will help in designing the energy efficient residential buildings in future.

Keywords: International Energy Conservation Codes (IECC), residential buildings, electricity consumption, envelope, U-Value

Introduction

Depletion of natural resources and the current energy crisis in Pakistan has affected the development progress. Like many other developing countries, Pakistan has also been unable to manage their natural resources for sustainable future needs.

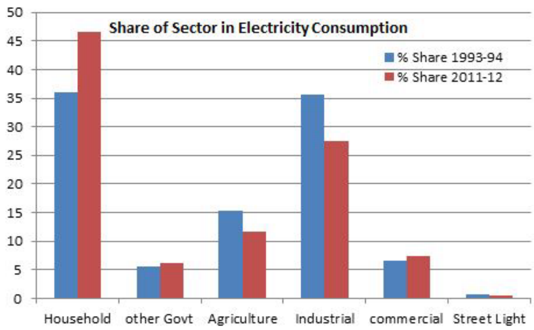

Figure 1 Share of electricity use in various sectors

Residential sector in Pakistan is the major consumer of energy in the form of electricity usage. Figure 1 shows comparative increase in the total consumption of electricity by household during 1994-2012.

One of the most important strategies used to conserve energy in buildings is the establishment of building energy conservation codes (BECC) and the standards for the design of energy efficient buildings. A comparison with and without the application of building codes in Denmark is shown as an example in Figure 2. With three types of houses (small, medium and large) and the percentage of small houses being higher in comparison to the others, resulted in a substantial reduction of total energy consumed. From 1900 to 1959, almost similar amounts of energy were consumed. From 1960 onwards, through the application of codes and their regular upgrading in all types of houses has systematically regulated energy consumption.

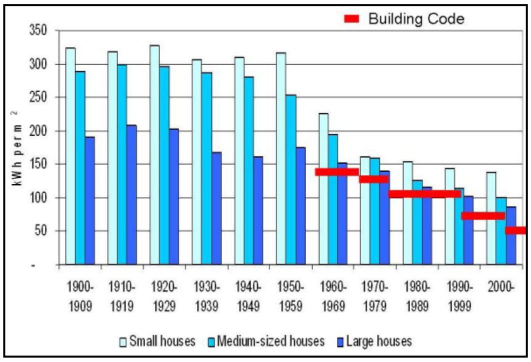

Figure 2 Reduction in energy consumption due to application of codes, Denmark (IEA G8 Plan 2008)

Though most energy efficiency requirements in building codes followed local, state or national tradition, the past decade has shown a trend in supranational collaboration to develop international energy efficiency standards. Examples are the US based Energy Efficiency standards (IECC and ASHRAE) which are used in US and Canada, and the European Energy

Performance in Buildings Directive (EPBD) that required member states of the European Union to establish standards for energy efficiency in new buildings. *(NW 2002)*

Many developing countries have used these standards a basic guide line to develop their own energy codes. Building codes of Pakistan has also been developed by the review of 90.1 ASHRAE standards, that are accepted model for commercial buildings internationally. This effort is made workable by the collaboration of local agencies with the ASHRAE. ASHRAE has increased its network to develop energy efficient standards which address the world's common goal and their achievement. As a matter of fact they have one of their operative chapters working in many countries including Pakistan as well. So it has become an international trend to review and compare the energy efficiency requirements for new buildings according to local climatic, context and traditions.

1.1 IECC for residential buildings

The International Energy Conservation Code (IECC), was issued in 1998, it was an updated version of model energy codes developed in 1995. According to IECC, buildings that are equal to or less than three stories are termed as residential dwellings. (IECC 2009) There are various sections that specify scope, administrative, enforcement policy, general requirements of climate zone, design condition and their corresponding requirements of envelope, systems and equipment. There are different types of regulations exist in IECC, based on the varying energy saving objectives e.g. Prescriptive, simulated performance method as alternative and model building regulations.

2 Process development for assessment of energy conservation codes

While developing a process to access the residential energy conservation codes according to the standards set by IECC, the foremost thing is the identification of climatic zone that must be generated from the local climatic design parameters of annual mean temperature values.

2.1 Climatic data analysis

Climatic zone provides a major challenge to the home design in terms of heating, cooling, insulation requirement, material selection, sunlight penetration and other construction techniques etc. Zoning is the first step in defining codes for a particular area because all the threshold values are dependent on it. The standard procedure defined in both IECC helps to identify the zone with the analysis of climatic data. For calculation purpose, minimum one year daily mean temperature of Lahore was required. Weather data of Lahore for one day in each month of a year which shall be highest mean temperature at any one day of a particular month is calculated as shown in table 1.

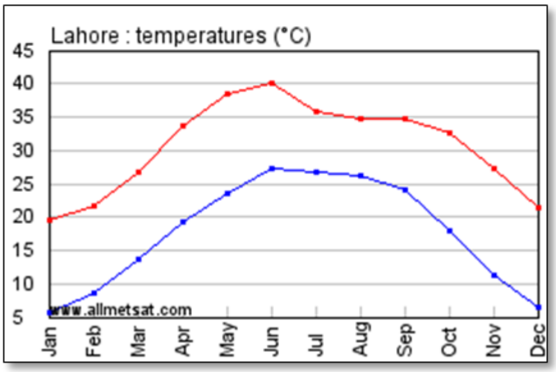

Figure 3 Annual mean maximum and minimum temperature (AMS)

2.2 Climatic data analysis through annual mean temperature of Lahore

First step is the identification of climatic zone using (Table 301.3[2] *IECC 2009)*, that defines and set requirements for the international climatic zone. All the calculations are based on SI units and cooling degree days (CDD).

In hot climate, a simple value to show the need for cooling is cooling degree days (CDD) and this is addressed by using a colder temperature than the designed indoor temperature for the calculation of cooling degree days e.g.: IECC uses baseline temperature as low as (10 C) for calculation of CDD. *(IEA G8 Plan 2008)*

The mean temperature data is conversed into cooling degree days by multiplying with days in a specific month of a year, which will give total value of CDD by adding all calculated values. The average temperature of Lahore based on CDD is found to be 5269 and calculated value overlap with the thermal criteria requirements of zone 1 as specified in the table 2.

Using the climatic table of IECC, that defined specification requirements for all the locations outside the united states and thermal criteria was established for the Lahore. The tabular data identified the zone number 1 is suitable for Lahore on the basic of calculated method of thermal criteria.

Table 1 Cooling degree days calculations for Lahore

1	2	3	4	5
Months	Mean temperature at any one day(MT) ˚ C	MT - 10˚ C (negative sign means zero)	Column 3 x days in month	Final CDD value (Adding all rows of Column 4)
January	12.6	2.6	80.6	5269 > 5000 So Included in Zone 1 of IECC
February	15.1	5.1	142.8	
March	20.6	10.6	328.6	
April	26.8	16.8	504	
May	31.8	21.8	657.8	
June	34.2	24.2	726	
July	32.2	22.2	688.2	
August	31.2	21.2	657.2	
September	29.9	19.9	597	
October	25.4	15.4	477.4	
November	19.0	9.0	270	
December	13.9	3.9	120.9	

Table 2 Thermal criteria calculation for hot dry region (Table 301.3[2] IECC 2009)

ZONE NUMBER	THERMAL CRITERIA	
	IP Unit	**SI Unit**
1	9000<CDD50° F	5000<CDD10° C

3 Identification of U-Value table

Comparative study of climatic data and thermal criteria helps in identifying the corresponding Insulation and Fenestration Requirements of various envelop components from Table 402.1.1 of IECC. So for the climatic zone 1, the corresponding insulation requirements identified in table 3, which are applicable to hot dry region of Lahore as well. (Ref; Table 402.1.1 of IECC 2009)

Climatic Zone	Fenestration U-factor	Skylight U-factor	Ceiling U-factor	Wood Frame Wall U-factor	Massive Wall U-factor	Floor U-factor	Basement Wall U-factor	Crawl Space Wall U-factor
1	6.81	4.26	0.20	0.47	1.12	0.36	2.04	2.71
2	4.26	4.26	0.20	0.47	0.94	0.36	2.04	2.71
3	3.69	3.69	0.20	0.47	0.80	0.27	2.04	0.77
4 Except Marine	2.27	3.41	0.17	0.47	0.80	0.27	0.34	0.37
5 and Marine 4	1.99	3.41	0.17	0.34	0.47	0.19	0.34	0.37
6	1.99	3.41	0.15	0.34	0.34	0.19	0.34	0.37
7 and 8	1.99	3.41	0.15	0.32	0.32	0.19	0.34	0.37

Table 3 IECC U-Factor for different climatic zones (IEA G8 Plan 2008)

4 Case selection criteria

A residential building as a typical representative for middle income families in Lahore was selected as a case study.

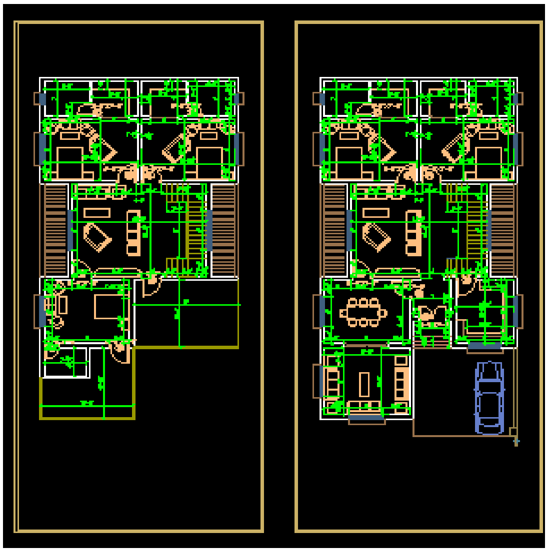

Figure 4 Plan of selected house

Selection Criteria was based on the following parameters. It should be

- in a Developed scheme in Lahore
- for Middle income families
- representative of commonly used local materials and construction techniques.

The selected house is located in Model Town. The covered area of the house is 3310 square feet, having two stories. (Figure 4)

5 Envelope material specification for base case and proposed options

Material specification of the thermal envelope using base case and the three different options which are closest possible to the international standards were worked out.

5.1 Base case

Option 1 was based on the thermal envelope materials which are commonly used in construction and are easily available in local market. Calculation of their current U-value is identified through specification of different envelope components.

5.2 Proposed options

Option 2, 3 and 4 are based on the improved U-Value efficiency and again major emphasis is on the local material available in market, so as to respect the ecological footprints of the buildings. (Table 4)

The first proposed option 2 was based on concrete block construction for wall, moulded beads of polystyrene sheet as insulation in roof so as to increase the time lag property of constructed assembly. Window pane glass is reflected material that increases the efficiency by reflecting the maximum amount of solar radiation that strikes the window surface.

The second proposed option 3 for the envelop was combination of cavity wall construction, improved insulating material in roof based in the principle of injection moulding that increases the labour cost but work efficiently and double glazed window with a vacuum in the between to maximize the solar radiation reflection. (Table 4)

The third proposed option 4 was insulated cavity wall, polyurethane as insulating material in roof and triple glazed window. This type of specification is quite expensive and above the affordability limit of middle class. (Table 4)

Table 4 Envelope material specifications for base case and proposed options

THERMAL CRITERIA	WALL	ROOF	WINDOWS	DOOR
Base Case\ Option 1				
U-Value (W/m2 K)	1.96	2.9	7.1	3.31
Solar Absorption (Opaque) / SHGC (Glazed)	0.7	0.9	0.3	0.578
Thickness (ft)	0’10”1/4	1’ ¼”	0’0”1/4	0’ 1” 9/16
Option 2				
U-Value (W/m2 K)	1.7	0.693	5.1	2.98
Solar absorption (opaque) / SHGC (Glazed)	0.6	0.9	0.81	0.5244
Thickness (ft)	0’5”1/4	1’ 1” ¼	0’0”1/4	0’ 1” 9/16
Option 3				
U-Value (W/m2 K)	1.204	0.602	3.4	2.31
Solar Absorption (Opaque) / SHGC (Glazed)	0.389	0.9	0.81	0.191
Thickness (ft)	1’1/4”	1’ 1” 8	0’1”1/2	0’ 1” 9/16
Option 4				
U-Value (W/m2 K)	0.52	0.52	2.6	2.26
Solar Absorption (Opaque) / SHGC (Glazed)	0.389	0.6	0.3	0.233
Thickness (ft)	0’ 11” ¼	1’ 3”	0’2”3/4	0’ 1” 9/16

6 Comparative review of existing and internationally proposed u-value

The figure 5 is giving a comparative review of the existing and internationally proposed U-value requirements for the different components of thermal envelop. The value defined internationally are according to the climatic study of warm arena and designed to increase the time lag of heat absorption from the outside environment, which occurs quickly due to thin material composition without fulfilling insulation requirement. This marked difference in U- value has led to the more heat absorption during summer and making environment uncomfortable for living. For all weather of a certain climate a specified U-value help in maintaining the temperature difference in a relative way that it does not affect the human comfort.

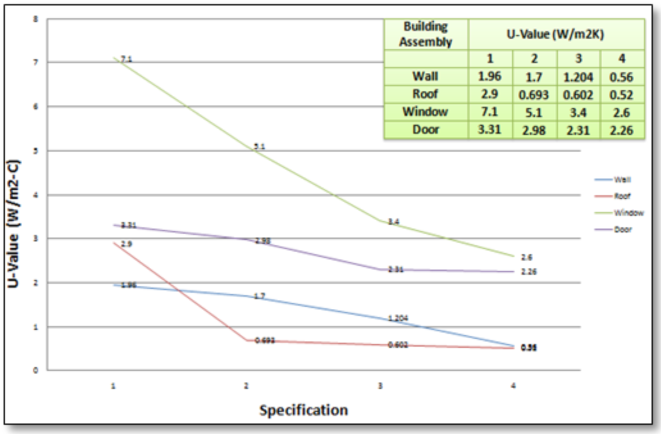

Figure 5 Comparison of U-Value of different building assemblies verses different material specification

A low U-value is always preferable to control the inside temperature of the envelope because it controls the thermal energy transfer from any building component with the size of 1 square meter [m²] at a temperature difference of 1 Kelvin [K]. *(ASHRAE 90.1)* So U-value of any material in skin heat loses of a thermal envelope is very important and needs a special consideration while proposing in any residential dwelling.

7 Computer simulation Ecotect v5.5

The model was simulated with the standard specification commonly used and cooling loads has been calculated and then model was simulated again on the basis of three proposed specification defined earlier. The calculation of the comparision in term of total energy consumed help to clarify the idea that by changing the material specification or by reducing the U-Value help in reduction of total energy consumed.

7.1 Simulation parameters

Following simulation parameters are imporatnt with respect to cooling load calculations;

1. Thermal zoning
2. Defining design conditions in terms of clothing (0.60), lighting level (27.9), and humidity (60%)

3. Occupancy level (varies between 3-6 person with refrence to activity of sleeing, resting, reading and walking
4. Assigned air conditioning hours to different activities

Table 5 Air conditioning operating hours

Activity	Operation hour	
	Weekdays	Weekends
Beds	20-07	19-12
Lounge	08-20	10-20
Drawing and Dinning	12-19	11-21

8 Total electricity consumption calculation

Following are the calculations that has been made for electricity consumption in selected residential building for middle income families in Lahore using commonly used local materials and standards as defined in codes (in the form of U-Value).

Table 6 Percentage saving for four different possible options

Specification	Energy Consumption (Wh/m2)	Energy saving
Option 1	964947	
Option 2	822159	15%
Option 3	620127	36%
Option 4	589802	39%

Comparing the possible energy saving calculation of commonly used and proposed options it was found that possible energy saving for proposed option varies between 15-39%, when compared with the base case. There is a steady increase in the value of graph as 15%, and 36% when choosing the 3rd and 4th proposed options respectively. Also there is an optimum point in the calculation where there energy saving is no more possible by varying the options (as shown in Figure 6).

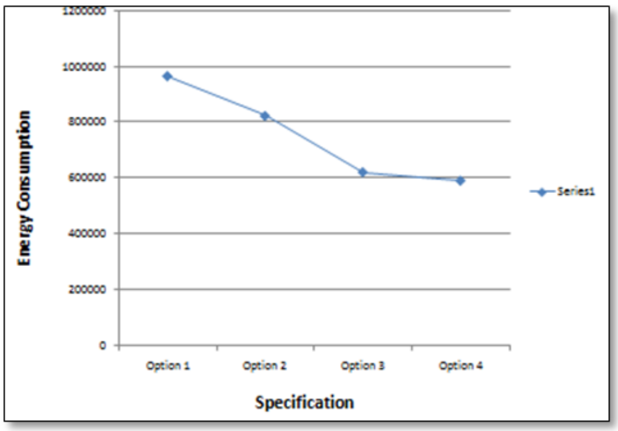

Figure 6 Comparison of energy being saved through different options of material specifications

9 Costing

Costing is a very important phenomena in house construction. While constructing houses, it's one of the considerable factors that force the home owner to set parameter of selection for their envelope materials. The choice between initial investments or compared to its focus more on the running investment must be on some solid ground. The awareness of the fact that initial cost of proposed options might be more but the running cost is more advantageous over the period of time. For this purpose the costing was done for various base case and proposed options.

Table 7 Percentage cost comparison of specification

Building Assemblies	**Total Cost (Rs)**			
	Option 1	**Option 2**	**Option 3**	**Option 4**
Roof	345347	552367	604122	646467
% Increase		37%	43%	47%
Window	23320	52470	183060	349800
% Increase		56%	87%	93%
Doors	63725	89250	116025	130900
% Increase		29%	45%	51%
Envelope	742268	1089411	1338537	1875909
% Increase		32%	45%	60%

For calculating purpose unit rate of each material was taken from Punjab portal website. They have defined the input rate of various construction materials corresponding to their requirements used to calculate bill of quantities. Finally, costing calculations was made for base case and proposed options. (Table 7)

The Figure 7 is giving a comparison of different proposed specification of their material envelope components and as a whole.

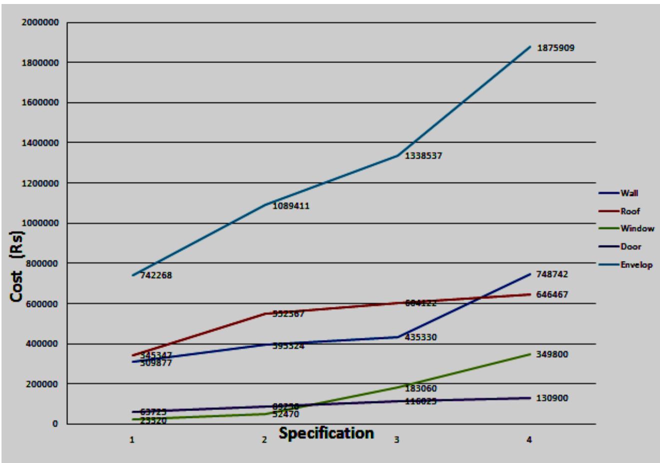

Figure 7 Comparison of costs of different building components verses different options

By changing the insulation material of the roof specification, there is an increase in cost. The insulation material selection in roof specification led to a sharp increase in costs while shifting from option 1 to option 2. However the costs exhibited a trend of steady increase when the quality of insulating material was improved in option 3, and 4. (Figure 7)

For walls, there is a steady increase in cost when the material used in option 1 was changed with the aerated concrete block (option 2) or cavity wall (option 3). However the changed insulating material (polystyrene, moulded beads) for option 4 resulted in much higher increase in costs.

Similarly, in case of windows, double glazed and triple glazed material specifications tend to double the cost as compared to the base case glass material.

Compared to all other envelop components, doors have nominal increase in their value throughout their increased trend in graph. (Figure 7)

Summing up all material envelop costs, the combined effect of all the specification of option 1 towards the next proposed option 2, and 3 is with a constant increase but for option 4, the increased trend in overall cost is very sharp due to improved level of insulation in selected building components. (Figure 7)

10 Initial investments and annual saving comparison

By looking at the reading in Table 8, it can be observed that option 2 has more initial investment due to the use of insulation material and changes made in the traditional pattern of base case. Its annual saving is nominal as compared to the increased difference in initial investment.

Table 8 Initial Investment and Annual Saving Comparison

No	Energy consumption KWH	Initial cost (Rs)	Running cost (Rs)	Difference of initial investment (Rs)	% increase in initial investment	Annual saving (Rs)	% increase in Annual saving
1	34118	3,242,268	219720				
2	29077	3,589,411	187256	347,143	10%	32464	15%
3	21430	3,838,537	138009	596,269	16%	81711	37%
4	20221	4,375,909	130223	1,133,641	26%	89497	41%

Option 3 has slight increased initial cost but gives twice the percentage of annual savings. Similarly for the option 4, the initial investment is very high as compared to the percentage increased in annual savings for this option.

11 Payback period calculations

Analysis of payback period was done which helps in recovering the increased initial investment of energy efficient houses. The payback time of all the proposed options ranges between 7-12 years. (Figure 8) In option 2 and option 4 initial investments is recovered in 11-12 years respectively. For option 3, this time reduces to a period of 7 years.

Option 4 has more initial investment, more annual saving and so has the highest payback time.

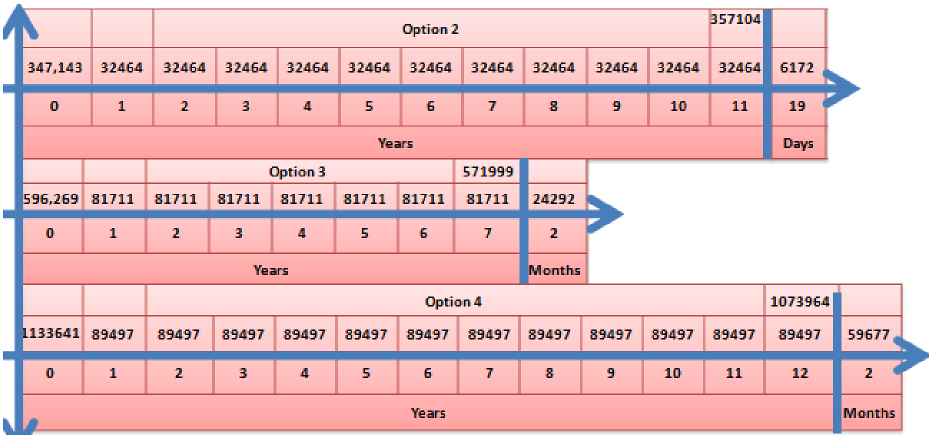

Figure 8 Payback time for proposed options

Proposed Option 2 has reasonable investment, annual saving but more payback time to recover the initial money. Proposed Option 3 has the least payback time of 7 years, 2 months in which the initial investment of the house is recovered and it starts paying back compared to the option 1 (Base case). So option 3 is more beneficial and easily convincible in terms of initial investment, annual saving and payback time.

12 Conclusions

Following conclusions have been drawn from the research:

1. IECC for residential buildings are the model codes, flexible enough to cater the climatic and design requirements of any country. Methodology opted for determining the climate and design characteristics of Lahore have provided substantial evidence in its support. Also the identified design requirements are applicable to all regions that fall in hot dry or similar characteristics.
2. International energy codes can give us a specification value with reference to the climatic zone that generally fits in the requirements without any background knowledge of local material. These material selections are very important from the social background and their frequent use over the period of time in the residential context of Lahore.

3. Through Computer simulations carried out in this research work, it can be concluded that 15-39% of the energy is saved with the application of closest possible internationally proposed U-Value corresponding to the climatic zone of hot dry region.
4. Consequently the potential extra cost range varies between 10-26% for proposed options. These increases initial investments have a payback time in the range of 7-12 years.
5. Through the comparison of different options, it is concluded that option 3 is best suitable solution for energy conservation for the studied case as it has comparatively less initial investment of 16%, increased annual saving of 37% and reasonable payback time of 7 years.
6. Different combinations of envelope materials help in reducing the energy consumption and encourage the phenomenon of energy saving within the residential buildings. With the variation of proposed options for material specifications, at least 15-20 possible combinations could be developed but those variations will be within the limit of 15-41% of energy conserved.
7. Determination of correct U-Value is very important. Observing the few decades practice of residential context of Lahore, there have been so many ignorance in term of material selection and specification recommendations. Comparing the existing followed U-Value that are found in most of the building and what internationally has been proposed for a particular climate similar to Lahore gives an idea of energy violation of thermal envelope in building practices.
8. Current practices focus on thin composition of different building components which provide short term benefits but are unable to last for supporting the energy saving phenomena.
9. Awareness must be increased among the stakeholders of construction industry to focus on the annual savings as compared to high initial costs. Since the initial cost of energy efficient house might be more yet its running cost is more advantageous over longer period of time. For most of the cases, it will start paying back after a certain reasonable period.
10. A passive technique of changing the material specification of envelope helps in reducing the substantial amount of energy being saved which can be further maximized by the intelligent design and incorporating other indigenous techniques.
11. A proposal for energy efficient house can reduce the domestic energy consumption substantially, increasing it resale value.

These types of houses are less polluted and have less adverse impact on the environment.

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