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Energy Efficiency in Traditional Newari Residential Buildings: A Case of Bhaktapur (Itachhen Tole)

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Abstract
Traditional architecture have some unique features to define themselves. Most of them follow passive solar architecture and are climate responsive. At the same time, these tend to be energy efficient. This research was conducted in order to know the essence of traditional architecture of Newari house in terms of energy efficiency. In this research, an extensive literature reviews were done to know about the traditional elements of Newari traditional houses and their connection to energy efficiency. The study had been divided into four phases: Literature study, Residential Energy Consumption, energy efficiency of traditional Newari building and state of traditional features of the buildings after earthquake 2015. A case area of Bhaktapur, Itachhen tole was selected to be the study area which composed of 80 households among which 20 percent sampling was taken for questionnaire. Structured questionnaires were constructed with the help of Kobo Toolbox and various variables were studied under SPSS analysis via independent charts and correlations. From literature reviews, rectangular plan, three and half storied with low storey height, clay tiled roofs, extensive use of mud and wood, vertical division of spaces, brick exposed facade and thick walls, carved doors and windows were found to be major traditional features of traditional Newari residential buildings. Survey results showed that residential energy consumption was dominant for lighting and cooking purposes. Energy use transition is found to be higher-from energy extensive to energy efficient appliances, energy types and sources. Vertical division of spaces, large openings, lower storey height and materials for building envelope were analyzed to be energy efficient traditional Newari features.

Keywords
Energy efficiency, Residential Energy consumption, Traditional Newari buildings, Passive solar design, Kobo Toolbox, SPSS analysis, correlation

1. Introduction

Traditional architecture is the one which was once upon a time designed and transferred by our ancestors to the newer generations. Today, due to the massive modernization and industrialization, many varieties of buildings are built. Looking to the traditional houses, there are several techniques that they behave with the environment friendly and at the same time are energy efficient. From the choice of the material and technology to the operation and demolish, traditional buildings remains more energy efficient in comparison to modern buildings. This is because they use passive solar building design principles in various building elements along with the use of renewable and locally available materials and technology. Across the world, many traditional building designs are found to be based on this principle.

Such buildings are characterized by specific type of planning, orientation, spatial layout, building elements and architectural elements. In Nepalese context, the traditional buildings have high tendency to save energy as they were designed in such a way that they can utilize non-renewable resources like sun and wind to the maximum, simply to say passive energy which ultimately lower the probable active energy consumption for room heating or cooling.

A typical Newari traditional residential houses are three and half storied buildings characterized by vertical planning of spaces, lower storey heights, use of locally available materials and technologies, large openings, etc. which makes itself energy efficient. They are planned in courtyard and the settlements are

compact or densely populated. From space minimization to the use of energy during construction, operation and demolish, Newari traditional houses stand energy efficient. But, today's trend shows a fast replacement of such energy efficient traditional buildings by the modern types. It is no doubt that the typical traditional houses are decreasing dramatically after the earthquake of 25th April 2015.

2. Literature Reviews

Traditional buildings are those buildings which were designed and built a long time back with the use of available materials, technology and manpower. Today, many studies have been done to enroot the fact that the traditional buildings are best solution and example for upcoming buildings for instance in term of thermal comfort [1], socio- economic aspects, social interaction [2], etc. But with these facts known to us, traditional building typologies are decreasing dramatically, being replaced which have been explained by several papers for example by artificial materials, modern designs and alien technology [2], by incongruous tall buildings with little emphasis on artistic taste followed by fast demographic changes and pseudo-modernization [3].

[4] states that traditional buildings use locally available materials which need lesser number of technological manipulations thus are energy efficient. They reduce the energy required for its transport, construction and operation. In addition to that, use of renewable energy resources in place of non-renewable energy resource is the second but parallel energy efficient technique that can be seen in traditional houses. Also, Low energy systems act as energy efficient ways that lowers the energy consumption in the indoor. The extent of energy saving done by replacing active energy systems with passive techniques is also a path towards energy efficacy [5].

The traditional houses in Nepal shows a greater inclination towards climate responsive designs which have a power to adapt with the harshness of climate to provide thermal comfort with very less use of active energy. They are designed depending upon the climatic regions; namely mountain, hilly and Terai [6]. Among various types of traditional houses prevailing in Nepal such as Tharu houses, Limbu houses, Gurung houses, etc., Newari house is one of the popular and aesthetically beautiful examples found in Kathmandu Valley.

As the paper has its major focus on energy efficiency of traditional residential houses, especially Newari houses, several papers were thoroughly studied to find out their relationships. A typical Newari house is characterized by several features like rectangular plan, usually about six meters with facades of various length but most commonly about four to eight meters, extensive use of mud and wood, lower storey height, usually greatest height up to 2.07m in average, sloped roofs approximately 2.5 feet above the attic floor level [**?**] with clay tiles baked in kiln known as āypā measuring 190x90x18 mm [7], lavish wooden doors and windows positions characterized by solar penetration through windows in different seasons in different angles i.e. lower angle sun in winter can enter to the interior but high angle sun in summer is avoided [8], vertical division of spaces namely Baiga (attic space for kitchen and dining), Chota (second floor for living area), Matan (first floor for bedrooms) and Chheli (ground floor for store)[6],etc. Energy efficiency in case of traditional Newari houses can be explained from several ways. [6] explains the orientation of the facade being south facing to receive maximum sunlight to gain heat and light The space planning is done in such a way that ground floor acts as a buffer zone to prevent cold from direct contact of ground with the bedrooms located at the upper floors. This reduces energy required for room heating. Furthermore, the attic space is used for kitchen which minimizes the chance of overheating the living and bedrooms, this ultimately reduces the chances of energy consumption required for room cooling Also, the use of large openings in living rooms usually located at the second floor receives adequate amount of sunlight of lower angle to heat up the room naturally in cold seasons, this cuts the energy required for room heating.

Brick exposed facade and load bearing walls are the characteristic features of a typical Newari house. Walls are of various widths differing from the floors or also same throughout the building. Similarly, [**?**] has found average thickness of wall 0.42 meters which is about one foot four inches. These thick walls act as thermal mass and serves as heat energy storage tank to emit heat to the interior in winter. This directly saves the energy required to heat up the rooms in cold seasons approximately 10 to 20 percent [1] which shows tendency of energy efficiency of traditional buildings.

3. Research objectives

The main objective of the study is to assess the energy efficiency of traditional residential Newari houses. The sub objectives are to find out residential energy consumption pattern of selected study area, to find out traditional features of Newari houses through extensive literature reviews and to find out relationship between the traditional features of Newari house.

4. Scope and limitation of the study

This research is to detect household energy consumption particularly on cooking, lighting, on appliances, heating of the selected case area and check energy efficiency of traditional features of Newari residential buildings by preparing correlation charts and interpretation. Other types of buildings are not taken into consideration, only residential buildings are chosen for study. Structural parameters are not included.

5. Research methodology

The research has been conducted in the residential buildings located at Itachhen tole, Bhaktapur which resides 80 residential buildings. Sampling is done by choosing 20 percent of the total number of residential buildings in the case area. They were selected in random manner. This sampling exhibits the representative of rest of the residential households in the specified area.

The structured questionnaire survey was carried out to gather and analyze data from sample households. These questions were formulated aiming to gather data firstly regarding the demographic features such as economic status, family size, preference, secondly traditional features like building façade, spatial layout, use of buildings, storey height and energy consumption. Closed questions were prepared via Kobo toolbox using different variables scales such as ordinal, interval and ratio scales. The subjective response of sample population were then analyzed and interpreted in objective measurement with the help of independent charts and correlation charts obtained from SPSS Analysis.

6. Research Context

The research has been conducted for the residential houses in Itachhen tole, Bhaktapur which is demarcated by two different gates, one being located nearby Na:Pukhu and another being the entry gate of Bhaktapur Durbar Square. This site was purposefully chosen as it is located next to the Bhaktapur Durbar Square where a completely conserved traditional Newari architecture can be seen. Wide varieties of elements such as pond, temples, buildings and cultural centres like Bahal and Bahis are located within its proximity.Two Bahis namely Kothu: Bahi and Thathu: Bahi are situated to the South-east and North-east border of the selected site. Na:Pukhu is located to the southern part of the site and Bhaktapur Durbar square is at the Western direction. The houses which lie on the linear street from the western gate to eastern gate are interrogated. Most importantly, the traditional features of Newari architecture is still well maintained or in the verse of conservation initiated by Bhaktapur municipality as Bhaktapur Durbar Square falls under World Heritage Site. The specific area chosen for research i.e. Itachhen tole is located in between two settlement with different levels of conservation norms. One is Bhaktapur Durbar square itself with a complete conservation bye-laws where buildings and monuments have to abide the rules of conservation strictly while houses located to the West of Itachhen tole have flexibility in choosing building features. Study on this area gives us varied influences of traditional Newari as well as modern features. These buildings with varied features which are capable of giving different answers are then comparable which are helpful to study the deviation in energy efficiency.

Figure 1: Overall case study street

7. Analysis and Findings

7.1 Demographic findings

Among 16 respondents, 11 were male while rest of them was female. Majority of the respondents were Newar which contributed 63 percent dominance by

Newar people followed by 31 percent Brahmin and 6 percent by Magar. In addition to that, religion followed by most of the people was found to be Hindu and Buddhism. 8 among 16 respondents were found to have Bachelor degree or less while rest was found to have either Intermediate or Masters or Phd degrees. Family type in the surveyed location has been found to be around 50/50 with 8 joint family and 8 nuclear family.

7.2 Energy Consumption pattern

7.2.1 Cooking

From the survey, LPG gas stove was found as the major appliance for cooking. Among electrical appliances two types were seen which rice cooker and earthen heater. These were found to be used to equal extent. Different from all, Traditional stove also seen.

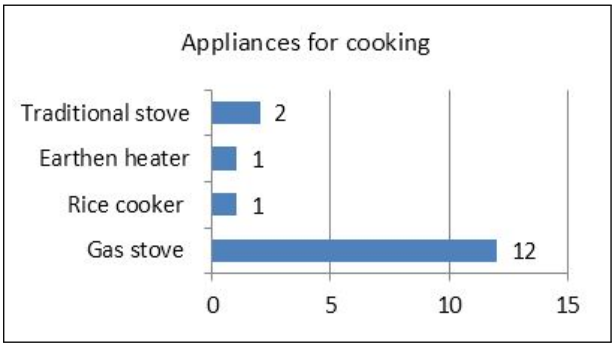

Figure 2: Appliances for cooking

7.2.2 Lighting

To check the type of lighting appliances in the sample area, respondents were asked about the existing lighting appliances they have been using in their respective houses. From the survey, it was found that the use of LED tube lights and CFL bulbs were intensive but lesser to than of LED bulbs. This shows that energy extensive lighting appliances such as Fluorescent lights and candelescent or filament lights is replaced by energy efficient lighting appliances such as CFL, LED bulbs and LED tubelights which shows that the settlement is aware of energy saving through their choice of energy efficient lighting appliances.

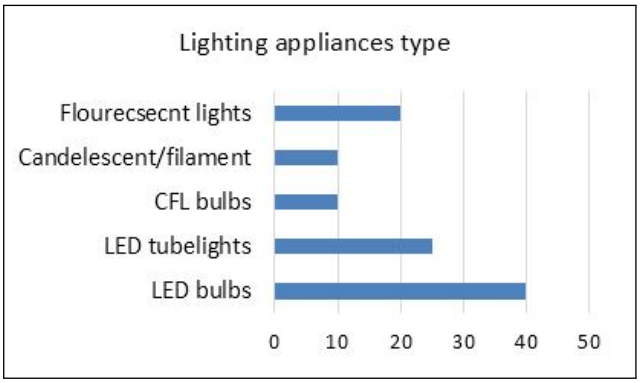

Figure 3: Type of lighting appliances

7.2.3 Water Heating

Water heating also contribute larger portion of energy consumption during the survey water heating in the case area was found to be done by using electric heater, traditional stove, LPG gas/ Geyser, and induction heater. The use of Electric heater for water heating purpose was seen dominant over other appliances.

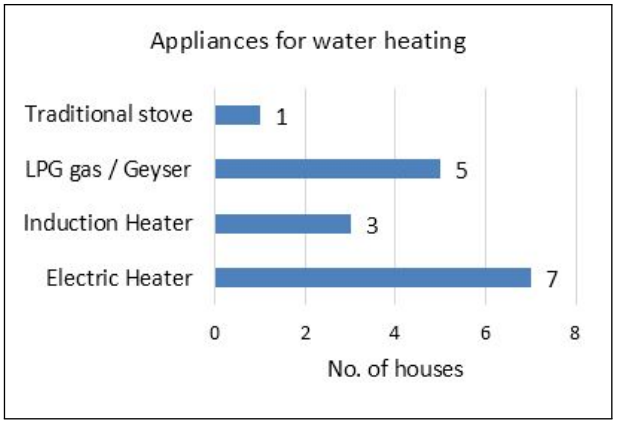

Figure 4: Energy consumption for water heating

7.2.4 Room Heating

The survey result shows the requirement of room heating for three coldest months namely November, December and January. The coldest month is January and it requires maximum room heating compare to

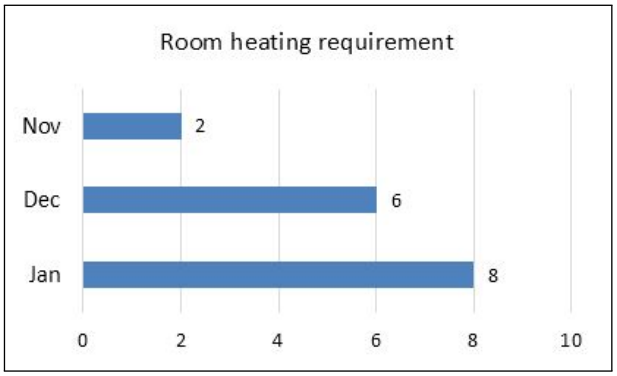

Figure 5: Months requiring room heating

November and December.

Different from preferences for source of energy required for room heating, electric heater is seen dominant over fire wood. Out of 16, 14 of the houses have been found to be using electric heater for room heating while rest use firewood.

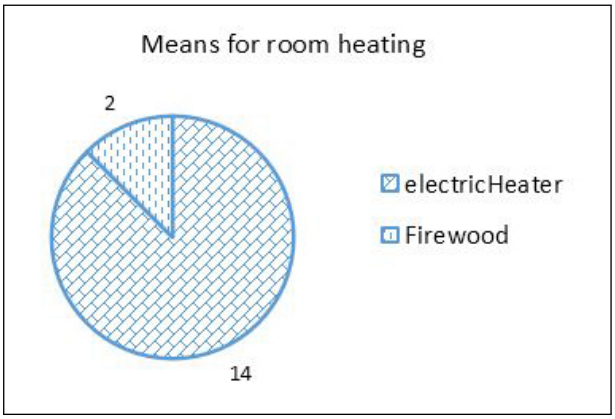

Figure 6: Source used for room heating

7.2.5 Room Cooling

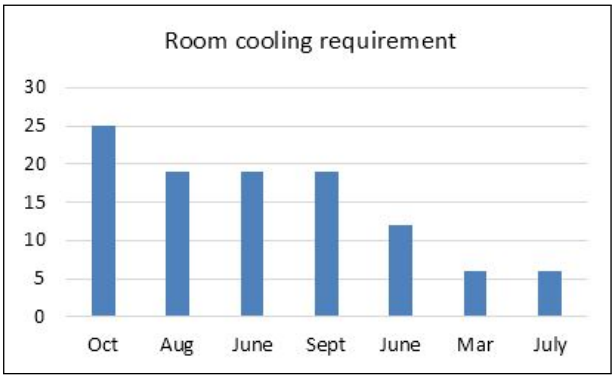

Figure 7: Months requiring fan

Among above mentioned months namely March, May, June, July, August, September and October, case area of Bhaktapur experiences maximum need of room cooling at October followed by August. The least energy is required for July.

7.3 Energy efficiency of traditional features

From the energy consumption pattern, we can see that most of the energy consumption is done in form of electrical appliances either they are for cooking, lighting, room heating, cooling and water heating, thus, electricity bill obtained during questionnaire has been taken a base for the comparison of different features of buildings residing in the case area and the findings are as follows. Characteristic features of traditional Newari residential buildings obtained from literature reviews and site surveys are tallied with energy consumption separately one by one to achieve their relationship via correlations.To achieve these charts, cross tabs were achieved from SPSS Analysis of the data which were exported from Kobo Toolbox initially.The results were then studied thoroughly and interpreted to achieve the finding. During this process, energy consumption stands constant as they are obtained from the questionnaire and the features of traditional Newari house are different. Various traditional features are studied under correlation with energy consumption either in terms of Electricity units or the expenditure on electrical energy. This ultimately provides the actual relationship of the two parameters namely energy consumption and traditional features. The charts given below are the results obtained:

7.3.1 Age of building

Chart in Figure 8 shows that as the age of the building elongates, energy consumption is seen more. Very less energy is seen to be required for the traditional Newari buildings prevalent at the site with compared to the modern buildings which are built ten years ago only.

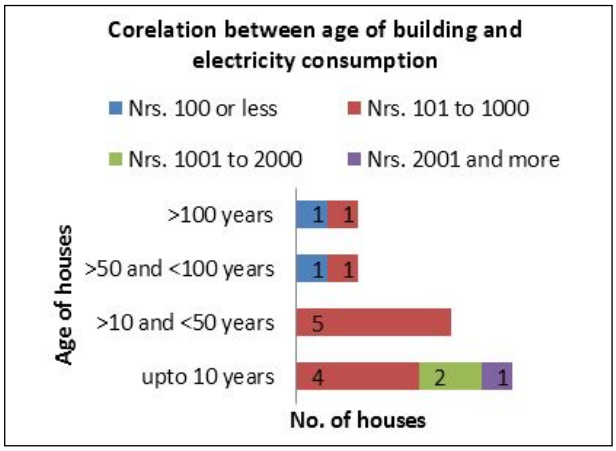

Figure 8: Relationship between age of building and electricity consumption

7.3.2 Building orientation

Chart in Figure 9 shows that South and East oriented buildings are more energy efficient than North and West oriented buildings. South orientation is one of the passive design strategies but in our case, street alignment is the major reason for these orientation.

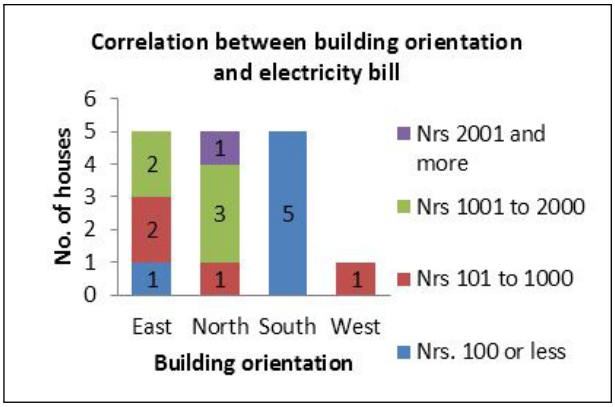

Figure 9: Relationship between energy consumption and building orientation

From the chart in Figure 10, it is clearly seen that the buildings having higher storey height are found to require more electrical energy compared to that of buildings having lower storey height. This particular feature of traditional Newari house stands energy efficient is clear from this finding from the survey.

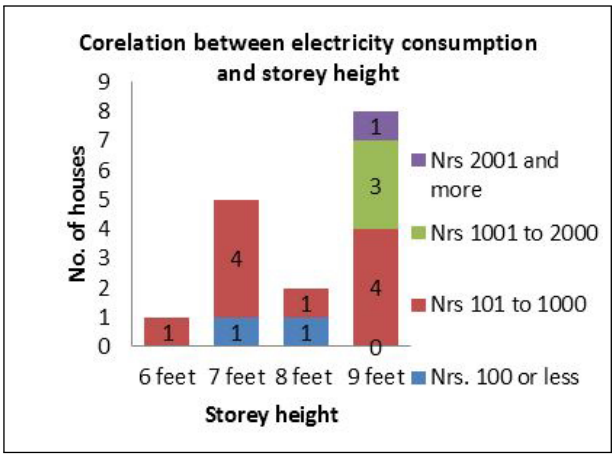

Figure 10: Correlation between electricity consumption and storey height

7.3.3 Building materials

Two different masonry namely brick cement and brick mud were investigated to represent load bearing and RCC houses. Above chart shows that the masonry used for wall can also be a reason for energy consumption. It also gives us an idea that the traditional Newari buildings behave energy efficiently due to the brick mud masonry as they are thick and capable enough to store energy. In addition to that, Brick cement masonry primarily representing modern buildings consumes more energy compared to that of traditional buildings.

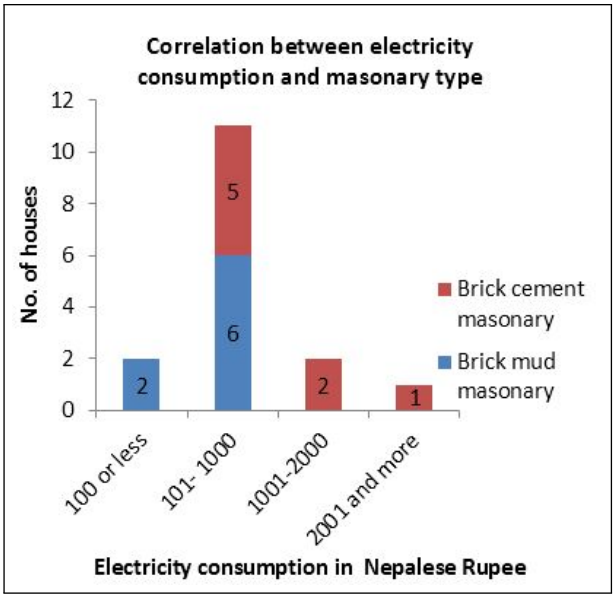

Figure 11: Relationship between Energy consumption and type of masonry

7.3.4 Vertical division of spaces

The chart in Figure 12 shows the energy consumption lower in traditional houses having vertical division compared to that with no vertical division of spaces. This can be taken as this feature of vertical division of spaces in traditional Newari house is good in terms of energy efficiency.

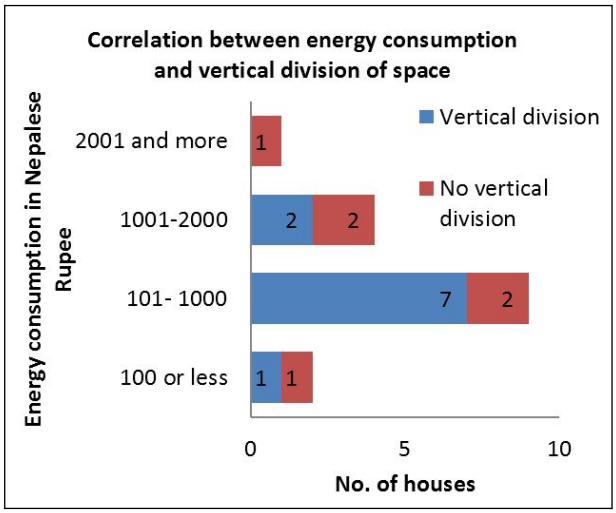

Figure 12: Relationship between energy consumption and division of spaces

7.3.5 Façade

As brick exposed façade has been made mandatory by the government to maintain traditional look, energy efficiency due to various types of brick façade were also studied and its finding is represented by the chart

in Figure 13. It is found out that the use of Kacchi Apa i.e. Sun dried brick for façade is less efficient than that of Dachhi and Chinese brick exposed façade. Comparing Dachhi and Chinese bricks, Dachhi Apa has been found to be more energy efficient. It can be also possible due to the moisture content higher in sundried brick and pores in the brick itself and also lack of airtightness with compared to Kiln burnt bricks.

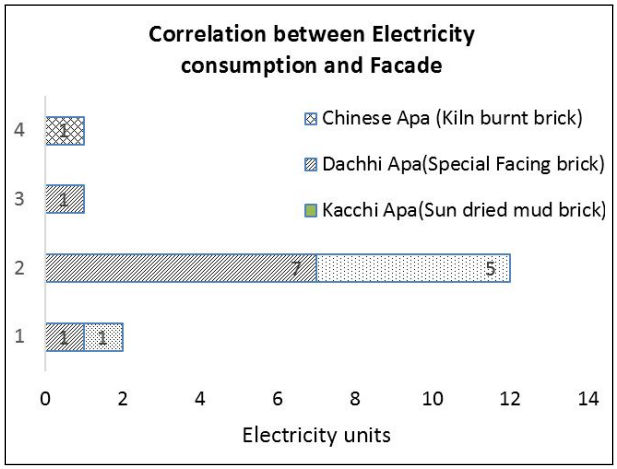

Figure 13: Relationship between Electricity consumption and Façade of the buildings

7.3.6 Thickness of outer wall

Chart in Figure 14 shows that the greater the wall thickness of outer wall, the energy efficiency is higher. As lesser units of electricity are consumed by the buildings having higher wall thickness, we can interpret the finding as wall thickness can directly enhance energy efficiency. This may be due to the thermal lag it creates.

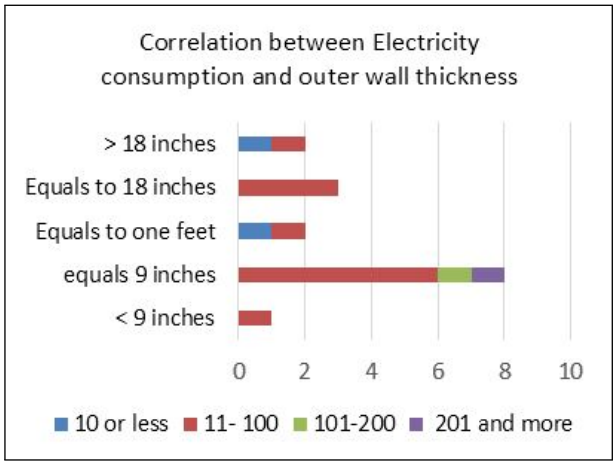

Figure 14: Relationship between energy consumption and external wall thickness

8. Conclusion

a. The residential energy consumption in Itachhen tole, Bhaktapur is active in cooking and lighting throughout the year. Room heating and cooling is required for certain extreme cold and hot seasons. Energy efficient appliances are extensively used. The major fuel used is electricity.

b. Traditional features of Newari residential buildings are rectangular plan, three and half storied, low storey height, vertical division of spaces, lavish carved openings, extensive use of mud and wood, brick exposed facade, brick with mud masonry and thick walls. Energy efficient Newari traditional features are storey height, mud and brick masonry, vertical division of spaces, brick exposed facades specially of Dachhi Apa and thickness of walls are energy efficient traditional features of Newari residential buildings.

c. Age and orientation of building also helps in altering the energy efficiency of building to an extent. Orientation can help reducing energy consumption to a remarkable level, as it is one of the passive design strategy also, but in our case the change in orientation of building is governed by street alignment rather than passive solar architecture.

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