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Energy Consumption Pattern of Post Disaster Reconstructed Residential Building: A case of Dolakha Town

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Abstract
Buildings are the greatest energy consumer of the world making up more than one-third of all final energy consumption and 37 percent of global final energy use [1]. In Nepal, residential sector accounts for 80.36 percent of total energy use [2]. The energy consumption in the building sector has increased because of our increasingly modern lifestyle and blindly imitating modern architectural style. After Gorkha earthquake 2015, post disaster recovery framework offered various building typologies for the building reconstruction that focused more on seismic standards. The reconstructed buildings lack thermal comfort inside the building in both summer and winter season. The purpose of the research was to examine overall energy consumption pattern of post disaster reconstructed residential building of Dolakha town which is one of the worst affected areas. The study method used was survey research that included random sampling of fifteen post-disaster reconstructed residential building from several toles of Dolakha town. Most of the young people of Dolakha have emigrated which has limited the use of energy in the building. The research found that the energy consumption pattern is characteristics of cooking, heating, and lighting. Number of people residing in the reconstructed building are two-four and are of age group (30-59). As a result, the study comes to the conclusion that hydroelectricity is the major source for lighting and for cooking and water heating purpose LPG gas, accounts for the majority of energy use. Only a small percentage of homes use solar water heaters. For room heating purpose coal and firewood are extensively used which has several environmental and public health risks. This shows that the town is completely dependent on non-renewable energy sources like LPG gas. The households do not focus much on the utilization of renewable resources. Solar energy can be utilized for water heaters and space heating.

Keywords
Energy consumption pattern, post-disaster reconstruction, residential building, Dolakha town

1. Introduction

Energy pattern can be defined as how it is used overall [2]. Energy consumption pattern includes consumption of commercial source like crude oil, petroleum products, etc. and non-commercial source of energy like firewood, cow dung, agricultural residues, etc. World's largest energy consumer are buildings that make up more than one third of ultimate energy consumption and 37 percent of all final energy used globally [1]. In Nepal, residential sector alone consumes 80.35 percent of the total energy consumption [3].

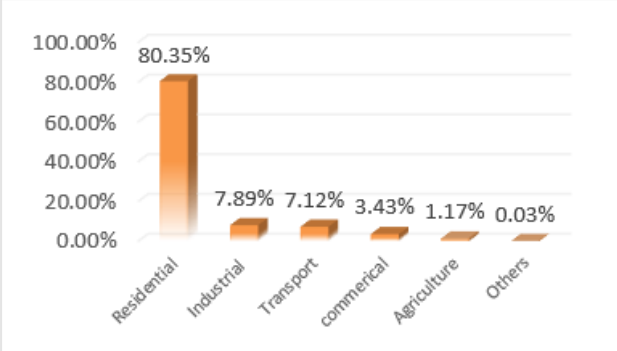

Figure 1: Energy consumption by residential and other economic sector Year (2011/12) Source: [3]

Huge amount of energy is used for lighting, cooking, heating/cooling, and ventilation. The increasing modern lifestyle and imitation from modern architectural style in the building construction has also increased the energy consumption in building

sector. Enhancing building's energy efficiency is a sustainable strategy to lower energy usage and its ensuing environmental impacts.

Gorkha earthquake 2015 and its subsequent aftershocks led to massive destruction of lives and infrastructures mostly in hilly regions of Nepal. Post disaster recovery framework proposed different building typologies for the reconstruction of hilly settlements that focused more on seismic performance and neglected the local climate and context. Almost all the buildings constructed after earthquake has the problem of being overheated during summer and severe cold during winter months. The increase in energy consumption is the result of building's inadequate thermal construction. Sustainability is a major dimension in post-disaster housing reconstruction, largely justified by energy consumption and management, which is analyzed through an understanding of the energy performance of the building.

The research aims to study and analyze overall energy consumption pattern of post disaster reconstructed residential building of Dolakha town.

2. Policies integrating energy efficiency and post-disaster reconstruction

A government's (or any organization's) approach to addressing challenges linked to the growth and utilization of energy, including its production, distribution and, consumption is known as energy policy [4]. Initiation has been carried out by government of Nepal to develop National Energy Strategy (NES) to address the obstacles and for the establishment and make sustainable use of energy resources [5]. The government of Nepal has built legislative and institutional mechanisms to carry out the long-term ambitions of Paris Agreement. Although there are no specific policies regarding building energy conservation by Nepal Reconstruction Authority (NRA), it has encouraged earthquake beneficiaries for the use of renewable solar energy in private housing reconstruction by granting incentives in final inspection. One of the key elements of Nepal's Long-term Strategy for Net-Zero Emissions by 2045 is to improve energy efficiency and maximize benefits by utilizing clean energy efficiently in residential industrial and transportation sector [6]. It has clear link to the achievement of Sustainable Development Goals (SDGs) by 2030 and beyond. Regardless of different policies related to energy sector, these policies have not covered the problem of residential sector.

Besides destruction and damage, the initial period of natural disaster also provides a valuable opportunity to rebuild and recover enhancing resiliency and saving energy. Numerous energy efficiency and resilience measures can be combined together in the built environment which further benefit each household through energy savings and minimize operating cost that reduce stress on energy infrastructure. Building energy efficiency in a new structure save more energy as compared to old buildings.

Lack of a clear and encouraging reconstruction policy; poor governance at the municipal and ward level officials; budgetary constraints to rebuild their homes; and the lack of a scheme and structure to facilitate local community-driven reconstruction activities are the major hurdles that inhibit energy efficiency integration in the post-disaster reconstruction.

3. Methodology

The study was carried out in mixed method research approach that included quantitative and qualitative research. The qualitative method was based on interpretation from literature review through different related articles, reports, documents. Similarly, quantitative research was done through questionnaire survey, interviews with the local people and study of case area.

The first step towards research started with literature review with the aim of developing research objective and generating ideas related to the research topic. Different policies related to energy efficiency and post-disaster reconstruction were studied and analyzed thoroughly. Similarly, Nepal's strategy for energy policies and programs were also studied that provided the pathway to conduct research. The old Newar settlement of Dolakha town was selected as case area. Climatic data from Department of Hydrology and Meteorology was used for detail study of climatic data of Dolakha. Structured and semi-structured questionnaire was prepared in Kobo Toolbox and tested that includes (demographic, building, and energy consumption pattern) details. Sample survey of ten houses were done including all the toles of core area of Dolakha town using the random sampling distribution method. Moreover, the selected household intends to incorporate all the

different building typology used in post disaster reconstruction Buildings constructed after earthquake 2015 was selected to conduct survey. Data were collected from questionnaire and the results are analyzed. Findings and conclusions are drawn from the analyzed data. The methodological approach of the study is illustrated in the figure below.

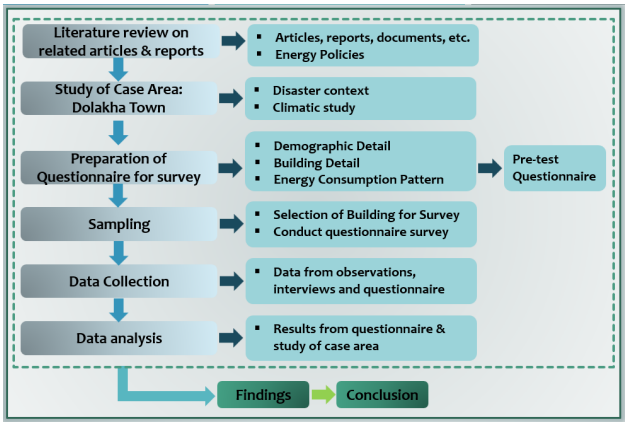

Figure 2: Methodological Approach

4. Limitations

The study is limited to the post-disaster reconstructed residential buildings of traditional core area of Dolakha town as the byelaws for the area is different from that of Bhimeshwor municipality. Since, survey was carried out using random sampling distribution method, the data interpretation will not contain the entire population but will instead show the energy consumption pattern of the settlement.

5. Research Setting

The case area Dolakha is a part of Bagmati province with Charikot as headquarter. It covers an area of 2191 sq. km and had a population of 186,557 according to Nepal census 2011. Its geographical location is latitude 27°47'37.68" North, longitude 86°11'03.48" East and at an altitude of 1700m. Dolakha lies in temperate climatic region of Nepal.

The research area Dolakha town is the village of Dolakha district located about 4.5Km North- East of Charikot in Bhimeshwor Municipality ward 2. It is inhabited by Newar community. Dolakha being an oldest town has great historic value. It covers an area of 20 hectares i.e., 0.2 Km2. According to 1988 census data, population of Dolakha town was 5,645 and according to census data of 2011, population was

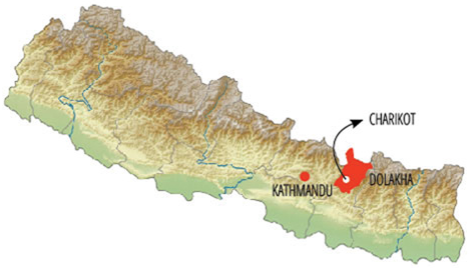

Figure 3: Map of Nepal showing Dolakha source: [7]

5,531 [8]. It is assumed that out of 297 families of the town, 215 families have emigrated to Kathmandu valley and other districts and foreign countries as well. As per the household survey by Bhimeshwor municipality in 2012, the total number of houses were 1,124 in Dolakha town and 338 households in core area of Dolakha town. [8]

6. Disaster context and Post disaster Reconstruction

After Gorkha Earthquake 2015, household survey was conducted by Bhimeshwor municipality, technically helped by National Society for Earthquake Technology (NSET) and Building Code Implementation Program in Municipalities (BCIPN). The total number of households in core area of Dolakha town was found to be 338.

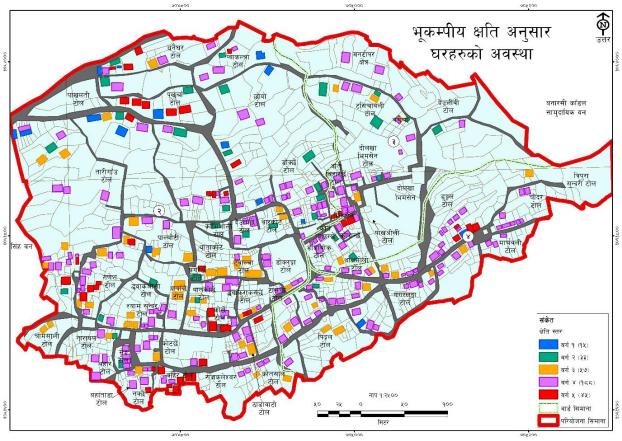

Figure 4: Mapping of Dolakha town in accordance with household destroyed by earthquake 2015 Source: [8]

From the survey, it was found that there were 15 households that are least affected, houses that are affected and needs repair are of thirty-three numbers,

fifty-seven houses can be used after retrofitting, 188 houses should be demolished for reconstruction and number of demolished houses were forty-five. The survey shows that most of the houses needed demolishment. [8]

7. Data Sets and Analysis

The results of the household survey conducted in Dolakha town are as follows:

7.1 Demographic Details

Only 13 percent of the respondents were of age group (18-29) years and 27 percent of (60-79) years while 60 percent were of (30-59) age group. From the survey data, it is observed that 80 percent of the families were joint before earthquake with 20 percent nuclear families. After the earthquake, there are now 27 percent of joint family and 73 percent of nuclear family.

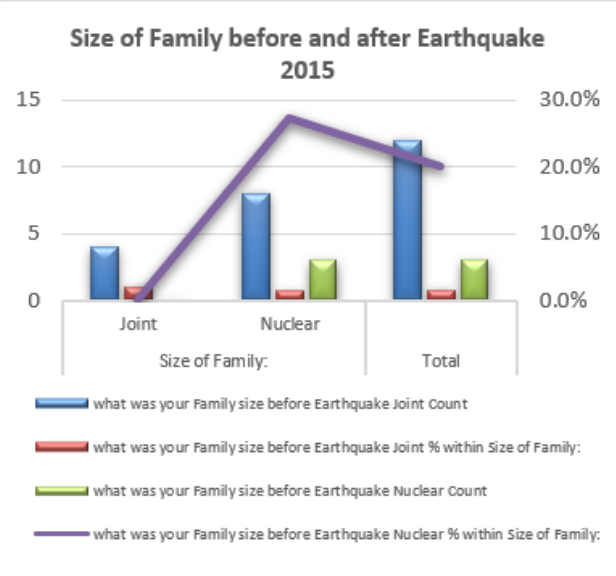

Figure 5: Size of Family before and after Earthquake

32.3 percent of the respondents are indulged in agriculture and service. 22.6 percent of the respondents have business as their occupation compared to 12.9 percent who have livestock farming.

7.2 Building Details

74 percent of the reconstructed buildings are of RCC frame structure with brick wall. Buildings with load bearing structure of stone wall with mud mortar is

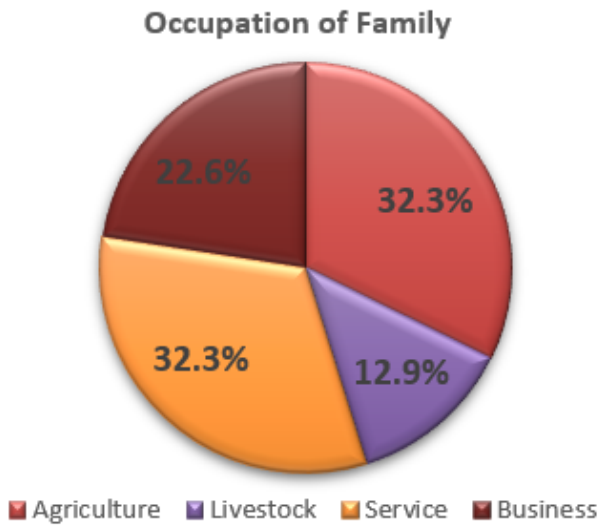

Figure 6: Occupation of Households

of 13 percent and the same percentage goes to load bearing structure of brick wall in cement mortar.

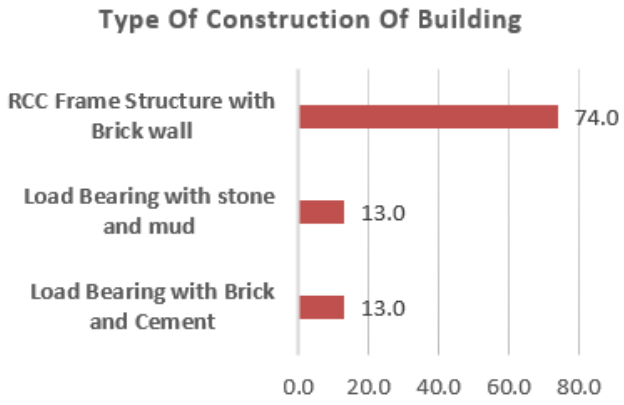

Figure 7: Type of construction of Reconstructed Building

As per the survey result, it is seen that 40 percent of the surveyed houses are of one storey and attic floor. 34 percent of them are of two storey and attic floor whereas 13 percent are of one storey with attic floor and the remaining 13 percent of three storey with attic floor respectively.

7.3 Energy consumption Pattern

7.3.1 Energy Use for Lighting

It is found that hydroelectricity, supplied by Nepal Electricity Authority is the main source of lighting for carrying out daily activities in all the household. Moreover, it is mostly used for lighting rather than using other appliances. Tube lights of (20-30 watt) and LED lights (3 watt to 15watt) were installed in

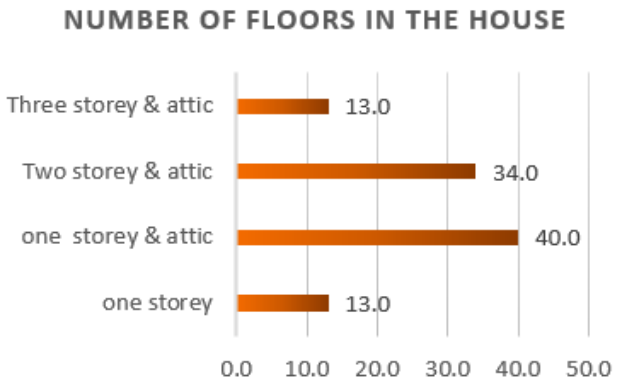

Figure 8: Number of floors of Post disaster reconstructed building

each room of every household. For outdoor lighting fixture, LED and CFL lights were used.

7.3.2 Energy used for Cooking

All the houses use LPG gas for cooking purpose with every household keeping one extra cylinder as stock. 72.5 percent of the houses use traditional stoves of coal and firewood for emergency purpose and secondary fuel for cooking. 25 percent of the households were found to be using electric rice cooker for 2-3 hours daily.

7.3.3 Applications Used

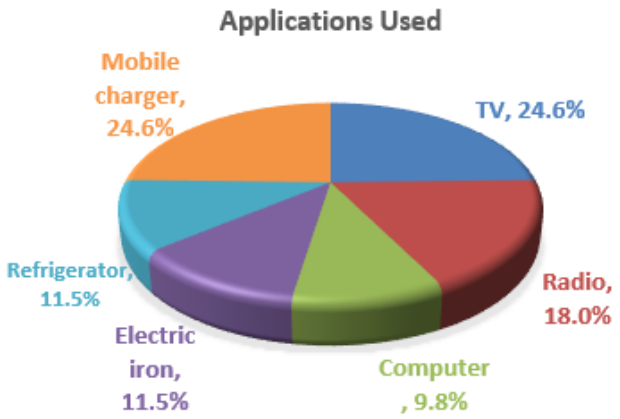

Figure 9: Applications Used in Surveyed Household

All the surveyed households have television and mobile charger that operate for 4-6 hours and 3 hours a day respectively. 18 percent households use radio. 11.5 percent of the surveyed houses have refrigerator and electric iron each. Only 9.8 percent of the respondents have computer/ laptop.

7.3.4 Energy Used for room heating purpose

For room heating purpose, 44 percent of the respondents said they heat their room by burning coal to achieve thermal comfort. Only 4 percent use LPG heater, 17 percent use electric heater and 35 percent use firewood.

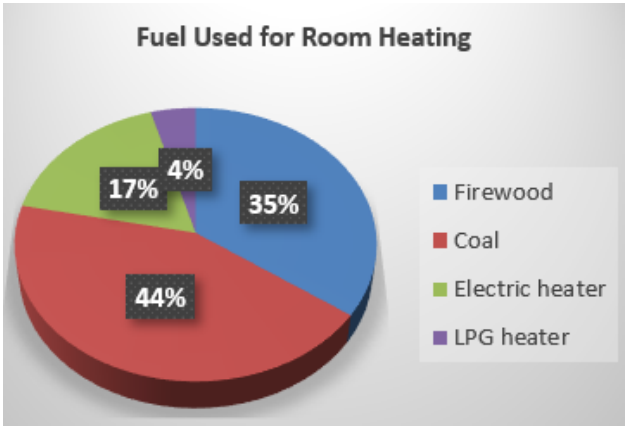

Figure 10: Fuel used for Room Heating

7.3.5 Energy Used for Water heating purpose

According to the surveyed result, 46 percent of the household use LPG gas for water heating while 29 percent use traditional fuel like firewood. 17 percent use LPG gas geyser and only 8 percent use solar water heater.

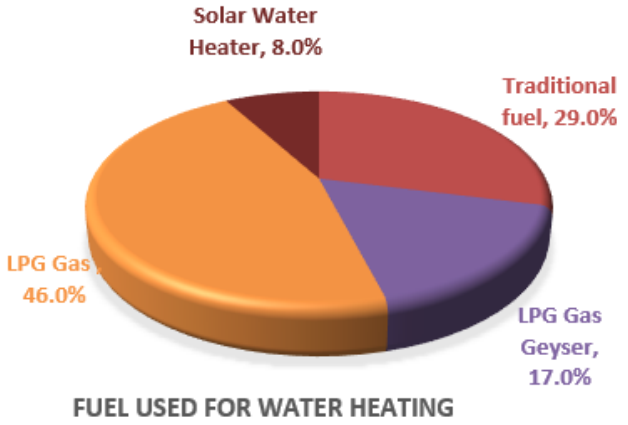

Figure 11: Fuel Used for Water Heating Purpose

7.3.6 Electricity bill per month

40.10 percent of the households have monthly electricity bill of Rs. (301-600) while 33.30 percent pay minimum charge of monthly electricity bill i.e., Rs 30.

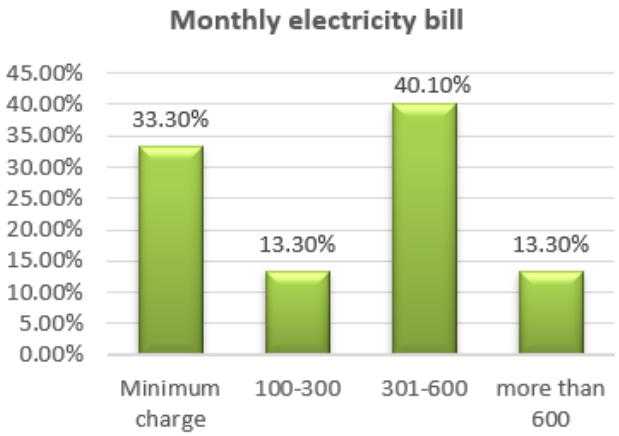

Figure 12: Monthly Electricity Bill

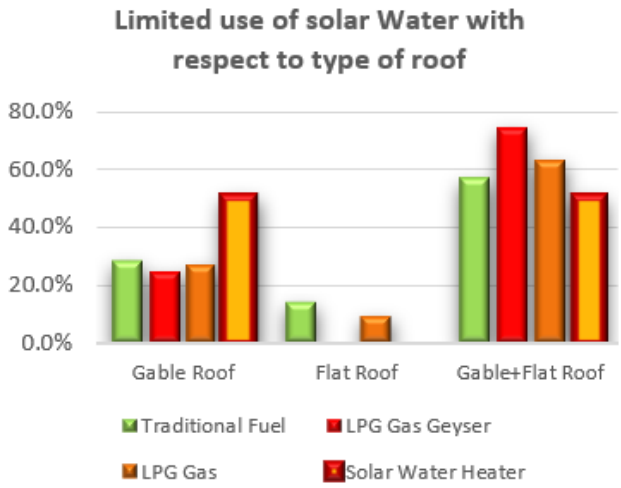

Figure 13: Roof Type and the fuel used for water heating purpose

8. Findings and Discussion

The investigation of the energy consumption pattern of post-disaster reconstructed residential buildings of old Newari town of Dolakha has been the main subject of the research. Although different energy policies have encouraged post-disaster building reconstruction to use renewable source of energy like solar power, it is not in use.

It has been discovered from the conducted research that most of the people living in the town are of old age or of age group 30-59. Young people are seen to emigrate to Kathmandu or foreign countries for study or employment opportunities. Number of people living in the house in most of the time are two-four. This has reduced the usage of energy through different sources. The buildings constructed after earthquake are mostly RCC frame structure with brick wall in cement mortar and are one storey excluding attic floor. Almost all the houses have used energy efficient lights like CFL, and LED. Use of incandescent lights were not seen during household survey. LPG gas is the primary source of energy for cooking with electricity being used for electric rice-cookers. Traditional stoves were used for cooking for cattle. Even if the survey's data indicates that people use different fuels like coal, firewood, electric heater, etc., to heat their homes during winter, thermal comfort is nevertheless maintained by wearing multiple layers of clothing. The use of solar water heater is very limited due to the use of slope roof of CGI sheets that can be justified by the chart below.

As shown in the chart below, the electricity bill varies according to the number of stories of the building. Due to the smaller number of people residing in the building, maximum houses have minimum monthly electricity bill i.e., Rs 30.

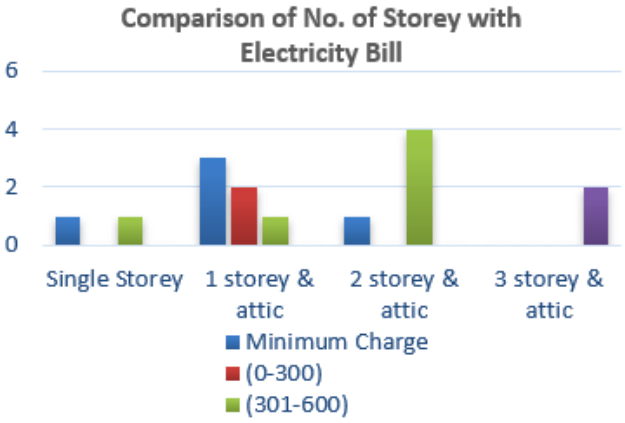

Figure 14: Comparison of monthly electricity bill with number of floors

9. Conclusion and Recommendation

The overall energy consumption pattern of post-disaster reconstructed residential building was studied through questionnaire survey and analyzed. The research found that the energy consumption pattern is characteristics of cooking, heating, and lighting. As a result, the study concludes that hydroelectricity is the major source for lighting and for cooking and water heating purpose LPG gas, accounts for most of the energy use. Only a small percentage of homes use solar water heaters. For room heating purpose coal and firewood are extensively used which has several environmental and public health risks. This shows that the town is

completely dependent on non-renewable energy sources like LPG gas. The households do not focus much on the utilization of renewable resources. Solar energy can be utilized for water heaters and space heating.

Solar water heaters can be used for water heating purpose that reduces the need of LPG gas heat water. Energy efficient building material and construction technology should be focused to reduce heating load in the building.

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