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Energy Consumption Pattern in Earthbag House in Nuwakot, Nepal

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Abstract
With rising environmental challenges like climate change and global warming, there is a huge interest in finding alternative building materials and technology that suits our structural needs as well as consumes less energy. Earthbag technology is widely regarded as the most promising of all sustainable construction methods. Earthbag technology is a sustainable and cost-effective construction approach with enhanced strength using ordinary soil. It does not require any industrial processing thus, reducing the global energy consumption and resource supplies. Earthbag technology has been accepted by the Nepalese government as one of the model houses for reconstruction, and it was also featured in the DUDBC catalogue volume II in 2017. This paper aims to investigate the energy consumption pattern in earthbag housing in case of Nepal. The consumption pattern differs with the building area, occupation of the families and their lifestyle. The main research approach applied for this paper is survey research. For the study, a questionnaire survey was carried out in Nuwakot district of Nepal where number of earthbag houses have been built. Electricity bills, family income, family size, electricity-using appliances, energy expenditures, and energy use for heating/cooling, cooking, and lighting have all been gathered. It is found that the major energy sources used in earthbag houses are electricity, firewood and LPG.

Keywords
Biomass, Earthbag Technology, Energy Consumption

1. Introduction

Around the world, earth architecture has been used regularly in the past. Although they have been in use for centuries, building permanent homes using earthbags is comparatively a new development. Originally, these earthbag houses were erected temporarily with the idea of transition shelter. The history of earthbag dates back to 1976 when Gernot Minke, head of the Construction Research Institute at the University of Kassel in Germany, started examining the use of natural building materials like sand and gravel in order to build homes without using binders [1]. Later in 1984, the idea of building permanent structures with bags filled with earthy elements was promoted by an Iranian-born architect named Nader Khalili. Actually, his initial thought was to stuff the bags full of moon dust. Attending a 1984 NASA symposium for brainstorming ways to build shelters on the moon, Khalili coupled the old sandbag idea with the ancient adobe dome and arch construction methods from his homeland in the Middle East [2] . Earthbag construction is a raw-earth construction method that involves filling varying-length sandbags with compacted earthen material such as clay and sand, together with straw and water, but almost any earth material can be utilized [3] . For a number of reasons, the earthbag technology is perfect for usage in poor nations. It doesn't require any industrial processing, which lowers the amount of resources and energy used globally. It uses resources that are readily available locally, which saves money and energy on shipping. Alternative construction technologies are appealing because of these elements. Designers have shifted to more practical construction techniques that use less energy during construction as a result of the rising cost of energy in the construction industry. Rammed-earth buildings are one of these methods because of the materials' accessibility, simplicity in preparation, and significant reduction in energy use and environmental impact. Earth-friendly materials

have a significant capability for thermo-buffering. They are among the most popular masonry substitutes. The main objective of this research is:

• To study energy consumption pattern in earthbag houses built in rural areas of Nepal.

2. Methodology

The nature of this research is based upon qualitative as well as quantitative research. The survey research method is the principal approaches used in this study. The site circumstances, demographic data, energy consumption patterns, and occupant thermal satisfaction are the main topics of the survey investigation.

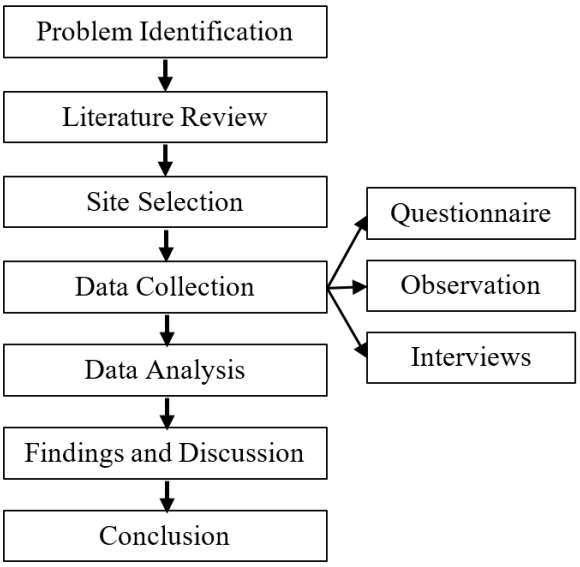

Figure 1: Methodological Framework

An exploratory study was conducted on a household level to determine the pattern of energy use and consumer preferences, as well as how they relate to the environment and socio-demographic characteristics. This study used a quantitative and a qualitative research methodology. This study included a socio-demographic survey, a questionnaire on home energy usage, and an analysis of the energy use trends in households. Six randomly chosen earthbag houses provided the data, which were then gathered. Electricity bills, family income, family size, electricity-using appliances, energy expenditures, and energy use for heating/cooling, cooking, and lighting have all been gathered.

3. Earthbag Technology

Energy is one of the essential components for any civilized civilization to function properly and to advance the socioeconomic advancement of the nation. According to Demirbas (2007), more than half of the world's population resides in rural areas, where they mostly rely on biomass as a source of energy and lack access to more contemporary forms of energy. Any reduction in energy use can have a major effect on the amount of energy used for the entire household.

Earthbag construction is a raw-earth construction method that involves filling varying-length sandbags with compacted earthen material such as clay and sand, together with straw and water, but almost any earth material can be utilized [3] . It's simple to make the case that earthbag construction uses the least energy of any long-lasting construction method. In terms of windows, HVAC, insulation, and water heating system heat performance, earthbag generally reduces thermal bridging, inefficient energy consumption, and optimizes heat performance in terms of energy and environmental sustainability.

Figure 2: Earthbag Construction

4. Energy Consumption Pattern

Energy consumption worldwide has increased steadily since the start of the Industrial Revolution, and the way that energy is used is what is known as its pattern. The globe utilizes a tremendous amount of energy, with fossil fuels accounting for a large portion of that energy. Energy supplies are not equally accessible, and global energy usage varies greatly. Over the past few decades, energy use in buildings has skyrocketed. People are spending more time indoors as a result of population growth and a technologically oriented society, which has boosted demand for indoor environmental quality and building functions. Energy use during every stage of a building's life cycle is

referred to as energy consumption. The pre-building phase, the building phase, and the post-building phase are the three main phases of a structure's life cycle, which can be used to reduce energy usage. Though energy use is not very efficient, Nepal nonetheless emits comparatively little CO2 when compared to other nations in the region. Among the various economic sectors of our country Nepal, the residential sector account for largest share in energy consumption followed by the transportation sector.

5. Study Area

There are only a few earthbag structures in Nepal, and most of them are schools (public structures). Even if residential buildings are built, a village has only one or two earthbag structures. Gerkhu village of the Nuwakot district has been selected as the study area. Nepal Reconstruction Authority constructed several homes in the Gerkhu village of Nuwakot using earthbag construction, making this location appropriate for the study. Gerkhu is located in Bidur Municipality's Ward 10 in the Nuwakot district.

The Gerkhu village's settlements are spread and dispersed in nature. Traditional buildings are often constructed with stone. Apart from the major building materials, the design and space division is similar to that of the traditional buildings. The buildings are two floors tall. While the upper floor is used to store grain and other household belongings, the elevated ground level serves as a living area and bedroom.

Figure 3: Aerial view of Settlement Area

6. Findings

The main mode of data collection was questionnaire survey. The questionnaire was divided into two major parts; socio economic details and energy consumption pattern. Results from the survey was analyzed and interpreted as following.

6.1 Socio-Economic Background

Nearly all of the responders from all the households questioned belong to the Sarki caste, and the settlement area is also known as the "Sarki Tole." Even though currently only a small part of Sarki are employed as cobblers or leather workers, making shoes has long been their traditional and primary line of activity. It was found that practically all of the families had agriculture as a secondary source of income. Some of the family ran their own businesses and ran their own stores to generate revenue. One family's member was found to be in a government service, but the other families were involved in labor. Also, one of the families was involved in construction industry as contractor and had higher monthly income than other households.

Figure 4: Major Occupation of the families

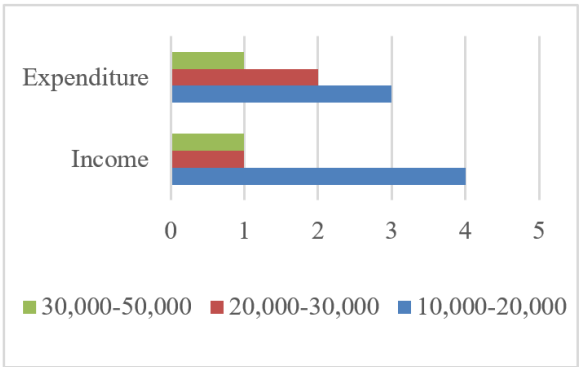

Figure 5: Monthly income/expenditure of the family

About 67 percentage of the household's monthly income is under the economic range of 10,000-20,000 Nepali rupees, 17 percentage of the household's monthly income is in the economic group range

between 20,000-30,000 Nepali rupees, and remaining 16 percentage of the household with income under 30,000-50,000. 50 percentage of the families had monthly expenses between 10,000-20,000 rupees, 33 percent have monthly expenses between 20,000 and 30,000, and 17 percent have monthly expenses between 30,000-50,000 rupees.

6.2 Energy Consumption

From the survey it was found that the major energy sources used in the settlement were electricity, firewood and LPG.

Table 1: Energy Types and their average consumption

Energy Types	Avg. Consumption per month
Electricity (kWh)	95.3 kWh
Firewood (Bhari)	8-12 Bhari
LPG (No.)	1 Cylinder

1. **Electricty**
   The primary supplier of electricity to the settlement was Nepal Electricity Authority (NEA). As there were no other energy sources, such as solar panels, lights could only be provided by electricity. Every home had CFL and LED bulbs installed. The LED bulbs were installed inside the house whereas the CFL bulbs were installed on the outside areas such as the porch area. However, firewood is also used for lighting and cooking sometimes when the electricity is cut off.

Table 2: Energy consumed by different equipment

Equipment	No	Rating (W)	Total Watt (W)	Avg. Use (hrs)	Monthly load (kWh)
LED Bulbs	3	12	36	6 hrs	6.5
CFL Bulbs	2	10	20	6 hrs	3.6
LED TV	1	55	55	4 hrs	6.6
Fan	2	50	100	8 hrs	24
Fridge	1	150	150	12 hrs	54
Mobile Charger	2	5W	10	2 hrs	0.6
Total					95.3

2. **Room Heating and Cooling**
   According to the survey, the residents felt very hot from May to August and very cold from December to February. Wintertime thermal comfort does not necessitate the use of any heating appliances. But summers are very hot and humid. The residents utilize table fans to stay cool throughout the summer even though the rooms lack any active equipment. The residence does not utilize an active heating or cooling system, yet the use of fans during the summer causes the NEA units to be greater than they are during the winter which results in higher monthly electricity bills in summers.

3. **Appliances**
   Generally, the equipment were utilized for cooking, lighting, and room conditioning. Due to the hot climate, people did not have a heating system for their rooms, but every household had fans for cooling purposes. Every home used a refrigerator, television, and phone chargers, per the survey.

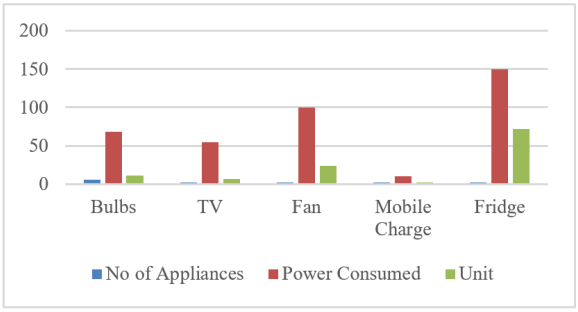

Figure 6: Electrical appliances and their power consumption

4. **Cooking**
   In terms of cooking, LPG stoves were used by all the households along with the 100 percentage household also using the traditional cooking stove. For water heating purpose traditional cooking stove is used. LPG and firewood were used as fuel for the kitchen appliances. According to the survey, households utilizing LPG require 20-25 bhari of firewood for the whole rainy seasons in addition to 1-0.5 LPG per month.

5. **Comparision of energy consumption pattern**
   Two different types of dwellings are present on the site. In one, there were two bedrooms on the ground floor, while in the other, there were three rooms. The size of the homes was determined by the number of family members

and their monthly income. When the energy consumption patterns of the two houses were analyzed, it was discovered that the smaller, two-room houses used less energy since they had fewer appliances. Appliances like LED and CFL bulbs, television, table fans, mobile chargers and a refrigerator were present in all the households whereas iron and electric heater were present in the bigger houses which is the three room houses. Also, number of appliances and their operation hours varied according to the family size.

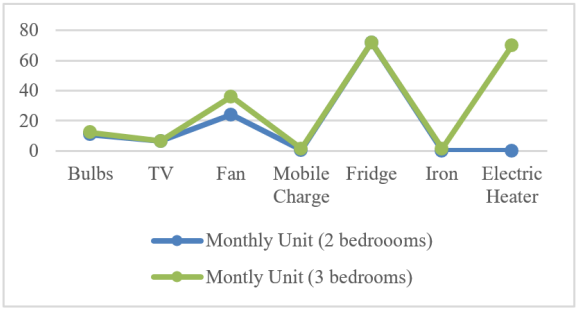

Figure 7: Monthly unit in different types of houses

7. Conclusion

In context of Nepal, this study examined the patterns of energy use in earthbag homes. These residences have been constructed for low-income groups of individuals. A thorough questionnaire was created that covered all demographic and socioeconomic information as well as the frequency of energy use. It was shown that these homes consume significantly less energy than modern structures, which may be a result of the neighborhood and socioeconomic position of the residents. The findings demonstrated that the desired energy carriers in earthbag homes constructed in rural areas depend significantly on the monthly household energy expenditure, monthly income, family size, dwelling size, housing type, land ownership categories, per capita energy expenditure, and educational status

Both the questionnaire survey and the on-site informal interviews revealed a pattern of similar energy use by the different appliances and their operation times. However, because the site was in a hot, humid climate, it was discovered that using the fridge and fans accounted for a higher number of power consumption. Additionally, it was discovered that, with the exception of earthbag houses with three rooms that had electric heaters for the winter, the monthly electricity bill in the summer is always higher than in the winter as other houses did not have any extra appliances for the winters. . It was amply demonstrated that the income of the household's members had a direct impact on the range of energy consumption among households. Households will switch from a traditional energy use system to an alternative energy use system when their income rises and their lifestyles change.

The major limitation of this paper is that the focus of this study is solely on the energy consumption patterns of earthbag homes. Other elements, such cost analysis and construction procedures, are not studied in this. The study is restricted to a single area in the Nuwakot district.

8. Recommendations

Apart from electricity, firewood is used for all heating and cooking needs. Therefore, it is essential to implement several crucial steps aimed at increasing the production of biomass energy while reducing carbon emissions, as well as at maximizing its utilization. Similar to this, the usage of alternative energy sources like solar panels should be encouraged in regions with high levels of solar radiation because they are effective over the long term. Additionally, it was noted that the summers are particularly hot, which leads to a high and sometimes insufficient use of fans to maintain a comfortable interior temperature. In order to maintain interior thermal comfort and reduce electricity usage in summer as opposed to winter, the space could be designed using more passive strategies.

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