Sustainable Energy Planning of Residential Sector: A Case Study of Bhanu Municipality

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Abstract: This study analyzes the energy situation of Bhanu Municipality, Tanahun, Nepal and examines the future energy projection for sustainable energy planning. The municipality occupies an area of 184 km^2. This research is mainly based on primary data and supported by secondary data from various sources. For collection of primary data, 152 random household samples were surveyed and the locals were interviewed on their energy consumption demand. Data analysis was done with the help of excel and LEAP software. Major energy sources in the municipality are forests, water resource, agricultural residues, animal dung and solar. Analysis shows that the total energy consumption of Bhanu municipality is 635.67TJ with per capita energy consumption is 12.69 GJ/capita. The main fuel for cooking in the residential sector is firewood with share of 80% supplied from private, government and community forests that covers 38% of the municipality area. Lighting is done through grid electricity, almost 98% of the households has access to grid. The analysis was made through different scenarios in LEAP, i.e., Low Carbon Emission Scenario, Efficient Cooking Scenario, Efficient Lighting Scenario based on municipal plans and Sustainable Development Goal 7. Low emission scenario is the policy intervention scenario in which electrification of end use demands is done for limiting the GHGs emissions.

INTRODUCTION

Energy is an inseparable component in modern society and is one of the constituents of socio-economic development of the country[1]. Energy intensity levels and trends differ widely across world regions, showing differences in economic structure and energy efficiency achievements. Efficient and reliable energy service provider in a country shows the good status of the country. So, its supply must be secure and enough. Global energy demand is rapidly increasing and the main concern is how to satisfy the future energy demand in a sustainable way[1].

The primary energy consumption of the world in 2019 is 193.03 EJ where oil holds the largest share of energy mix (33.1%). The data's shows that the rapid growth of natural gas and renewables in the recent years as compared to other fuels. The worlds per capita primary energy consumption is 75.5 GJ/capita. The carbon emission in 2019 is 34169.0 million tonnes of CO_2. Carbon emissions from energy use grew just by 0.5% from the previous year (2.1%)[2]. The carbon emission in 2019 is less than half 10-year average growth of 1.1% per year due to the short terms outcome of the covid_19 pandemic[2, 3].

The major energy resource base in Nepal consists of biomass, hydroelectricity, petroleum products, natural gas and coal. The country does not have own reserves of natural gas and petroleum products. The total energy consumption during the fiscal year 2018/19 is 14014.13 ('000 toe). Among them the traditional energy source constitutes 68.5% of total energy consumption, commercial constitutes 29.4% of total energy consumption and renewable constitutes 2.1% of total energy consumption[4]. Total population with access to grid electricity has reached to 86% in fiscal year 2019/20.

Energy consumption per capita is the energy efficiency indicator in the residential sector[5]. Nepal's energy consumption per capita is 245 kWh[6]. Also, Nepal aims to achieve the targets of SDGs by 2030. To achieve these targets Nepal has set the plans and policies. Thus, it is necessary to plan energy level of each municipal level in order to meet the national targets.

Problem statement: Nepal has set the target of graduation to LDC by 2022 and Middle-Income Country by 2030. The indicators for graduation are Gross National Income (GNI) per capita, Human Assets Index (HAI) and Economic Vulnerability Index (EVI). Nepal is about to achieve the threshold targets of HAI and EVI but the gap between graduation threshold and Nepal's position is increasing in terms of Gross National Income. GNI per capita is a directly proportional to the energy consumption per capita. So, the energy consumption of the country needs to be increased in a planned way to get the required economic growth rate[7].

Nepal being the member of UN has set targets to achieve the sustainable development goals by 2030. Nepal also included long term perspective with a 25 years vision in the 5th-year plan in order to promote the sustainable development. SDG 7 defines the energy sector targets. In Nepal, research, energy plan and analysis has been done only in the national level not in the local level. Since, national level plan does not suit perfectly to the local level due to variance in socio-economic factors. Hence, suitable plans should be made remaining within the constraints of each local level.

In developing countries, residential sector is accountable for majority of energy consumption, the value being 87% of total energy consumption for Nepal[8]. 70.6% of households in Bhanu Municipality use firewood for cooking which is the main source of GHGs emissions. Hence, in order to mitigate the GHGs emission and promote the use of efficient technologies and efficient fuel switching, sustainable planning of residential sector of Bhanu municipality to be carried out. Which not only helps for sustainable development of municipality but also helps to achieve different targets set by government and UN.

The main objective of this study is to study the energy, environment and economic effects of implementing sustainable energy access planning framework for sustainable energy development of residential sector of Bhanu Municipality.

Literature review

Study area: Bhanu Municipality is situated in Tanahun District of Gandaki Province. The municipality was established by the government of Nepal on 2073/11/27 in the name of legendry poet Adikabi Bhanubhakta Acharya by merging previous Bhanu Municipality, Basantapur VDC, Mirlung VDC, Risti VDC (Ward No. 6), Satiswara VDC (ward 1-5), Tanahusur VDC (Ward 1-3), Chowk Chisapani VDC, Rupakot VDC. The municipality lies 61km east of Pokhara. It lies at an altitude of 810m with latitude of 28°2'30 N and longitude of 84°21'10 E. The municipality is bordered by Gorkha and Lamjung district in the East, Byas Municipality in the West, Lamjung District in the north and Bandipur rural municipality and Gorkha district in the South. Table 1 shows more information about the municipality.

Figure 1 shows the location of municipality in the district map of Tanahun and location of Tanahun in the Gandaki Province.

Past literatures: In study[9], Shrestha analyses the energy situation of Bhojpur District for providing the basic information for planning and management. Cooking was done through traditional cook stove using firewood (95.5%). Use of LPG is increasing due to access to road. Shakya[01] in his study presented the benefits of low carbon and potential emission reduction taking the case of Kathmandu. In the study[11], researchers studied the energy consumption pattern and scenario analysis of residential sector of Kathmandu Valley using optimization model in MAED and MARKAL. The study found that the urbanization has increased the energy demand. If we continue to use the same technologies and the

Table 1: Information of Bhanu Municipality; Census in 2011

District	Bhanu municipality
No. of wards	13
Total area	184 km^2
Population	45.792
No. of households	12.097
Household size	3.79

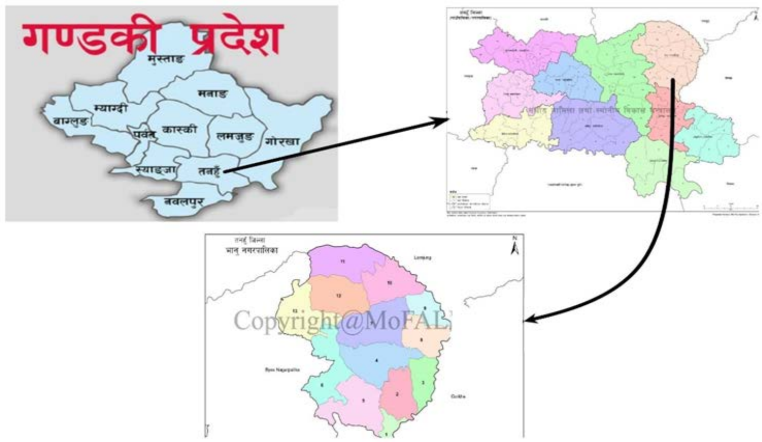

Fig. 1: Location Map of Gandaki Pradesh, Tanahun district and Bhanu Municipality[8] website mofga

urbanization continues to grow then within 20 years energy demand will be doubled. However, intervention of technologies and fuel switching helps to reduce the demand. In study[12], Panthi studied the emission and energy analysis of Reshunga municipality. The author analyzed the different scenarios based on national targets in LEAP. In the BAU scenario end year final energy demand will reach to 245.3TJ while in DSM and BSP scenario final energy demand will reduced to 230.7 and 216.2 TJ, respectively.

Similarly, many other studies are undertaken in the field of energy analysis, this study attempted to study energy and environment analysis of Bhanu municipality and forecasts up to year 2050 based on SEAP framework to achieve national level goals.

MATERIALS AND METHODS

The steps followed in this study are literature review, area of research and gap identification, sample size calculation for the area, questionnaire development, primary/secondary data collection and data calculation in excel, development of LEAP model, analysis from LEAP and final documentation.

Sample size determination: For sample size determination, Krejice and Morgan determine and publish a formula in the article “Small Sample Techniques” the research division of the National Education Association. The mathematical formula is:

$$S = X^2NP(1-P) \div d^2(N-1)+X^2P(1-P)$$

Where:

S = Required sample size

X^2 = The table value of Chi-square for 1° of freedom at the desired confidence level (3.841)

N = The population size

P = The population proportion (assumed to be 0.50)

d = The degree of accuracy expressed as a proportion (0.05)

Bhanu Municipality consists of 13 Wards and about 46179 populations. With the confidence level of 95% and the degree of accuracy 8%, the sample size found to be 149 households on conversion of fractional values to upper values 152 samples. After the determination of sample size, i.e., 152 households, the number of households were determined in each ward on the basis of percentage households situated in those wards. So that, data collection would cover households from all wards of Bhanu Municipality.

Selection of modeling tool: LEAP was used as a modeling tool. It is used because:

- It is easy and flexible to use
- It has broad scope: demand, transformation, resource extraction, GHG, etc.
- It requires less data inputs
- It is widely adopted tool for medium- and long-term planning

Formulation of LEAP model: For the analysis of energy demand and emission LEAP was used. The current energy demand of municipality was given as input based on the end use demand. The end use demand categorizes as: Cooking, cooking animal meal, lighting, preparation of raksi, space heating, space cooling, water heating, etc. The key assumptions are the populations and the per capita income of the people. Based on the energy elasticity of end use demand on population and GDP, the study is further carried out. Figure 2 shows LEAP energy demand disaggregation for Bhanu Municipality.

Table 2: Scenario summaries

Scenario name	Description	Assumptions
BAU	Business-As-Usual Scenario	Population growth = 0.94%, economic growth rate = 4.8%, energy intensity and energy mix remain constant
EFC	Efficient Cooking	Population growth = 0.94%, economic growth rate = 7%, replacing traditional firewood stove by ICS and by electricity based on SDG7
EFL	Efficient Lighting	Population growth = 0.95%, economic growth rate = 7%, switching to LED lighting based on SDG7
LOW	Low carbon emission	Population growth = 0.94%, economic growth rate = 10.5%, electrification in all end use demand at the end year

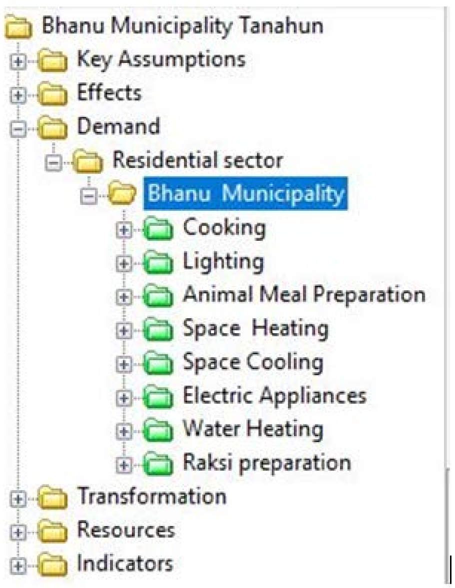

Fig. 2: LEAP model of end use demand

Scenario development: Scenarios are developed from the primary data survey and secondary data on demography, technologies and resources. Four different scenarios are considered in the research they are: BAU, EFC, EFL, LOW. Table 2 summarizes the assumptions of different scenarios.

RESULTS AND DISCUSSION

Firewood for cooking and electricity for lighting are the main sources of energy in the municipality. The total energy consumption of the residential sector of the municipality is 635.67TJ per year.

Fuel wise energy consumption: The main fuels used in the municipality are firewood, LPG, electricity and biogas. Firewood shares the 89% of total energy consumption. Firewood is used mainly in cooking. People use firewood which are easily available in private or government forests and does not cost much. Firewood is utilized in maximum amount for cooking animal's meal and preparation of local alcohol. Since, forest covered area is 38% of total land covered of municipality firewood is cheaper source for these end use demands considering the availability and monetary point of view. The use of LPG is increasing day by day due to its ease in use. Firewood, LPG, biogas are the sources of GHGs emissions. Hence, this research focuses on sustainable development by switching to the efficient fuel and technology. Figure 3 shows the fuel share of municipality in base year.

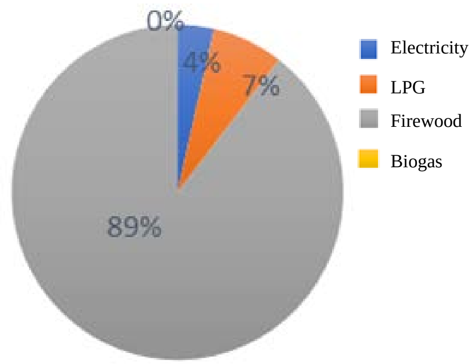

Fig. 3: Fuel share by end use demand

Energy demand of base year (2020): The total energy demand of the base year is 635.67 TJ. Where, cooking animal meal shares the maximum end use demand which is 257.45 TJ which is followed by cooking 229.43 TJ. Preparation of local alcohol follows the cooking and has demand of 83.09 TJ, lighting has the minimum end use demand of 5.47 TJ. Water heating, space cooling, space heating and electrical appliances has the energy demand of 17.60, 6.41, 26.44 and 9.48 TJ, respectively (Fig. 4).

Energy demand projection: In the LEAP different scenarios were created based on the national and municipal targets and plans. The final energy demand projection is done under the BAU, EFC, EFL, LOW scenarios. The final energy demand in 2050 is highest in EFL scenario which is 1312.23 TJ followed by BAU 1263 TJ followed by EFC 1015 and LOW 332.1 TJ (Table 3).

Emission analysis: The mitigation of GHGs emission is global concern of today. Figure 5 shows the GHGs emissions for each scenario. The per capita GHG emission in BAU scenario in base year is 72.43 kg. The BAU and EFL shows the gradual increase of GHG

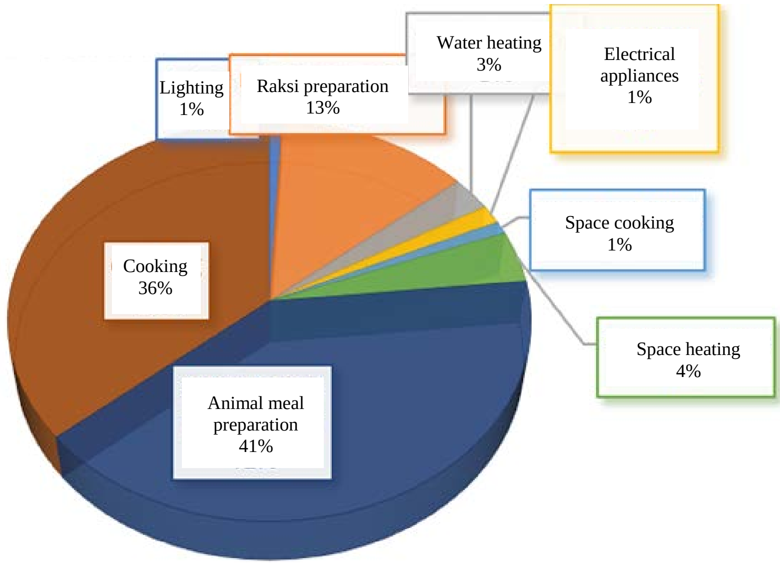

Fig. 4: End use energy share

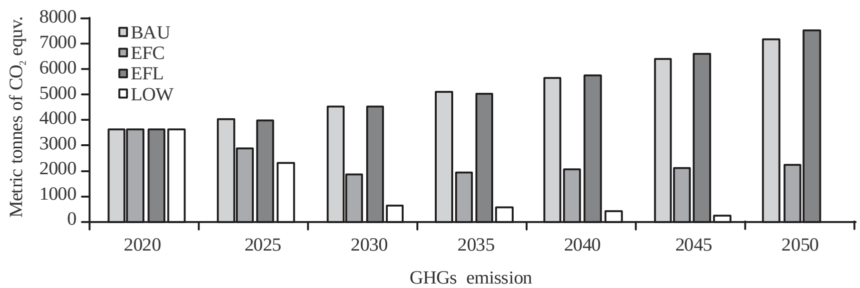

Fig. 5: GHGs emission projection under different scenarios

Table 3: Energy demand projection based on different scenario

	Energy demand						
Scenarios	2020	2025	2030	2035	2040	2045	2050
BAU	635.67	709.66	792.81	887.82	996.62	1121.15	1263
EFC	635.67	641.77	642.86	716.64	801.75	900.67	1015
EFL	635.67	712.99	800.70	902.44	1019.72	1155.61	1312.23
LOW	635.67	461.32	234.76	255.04	277.89	303.76	332.1

emission. Since, there is no intervention on fuels emitting GHGs. EFL intervenes only on efficient lighting scenario. In EFC scenario there is gradual decrease in GHG emission. LOW scenario is the policy intervention scenario where we want to reduce GHGs emission to very low value by electrifying in all end use demands. This shows gradual phase out of traditional and fossil fuel by electricity and solar reduces the emissions of GHGs and also local air pollutants. Reduction in emissions of GHGs and local air pollutants depicts reduction in environmental impact as well as human health impacts. EFC and LOW scenarios are favorable to environment and also human health.

CONCLUSION

The total energy consumption if Bhanu municipality in the base year 2020 is 635.67 TJ. the average energy consumption per capita is 12.69 GJ. There is high share of firewood in cooking human meals, cooking animal meals and preparation of local alcohol, etc. and for lighting purpose people are switching to LED but use of incandescent lamp is also abundant which is used for heating and lighting to small chickens. The energy projection for the end year is 1263.00 TJ based in BAU, 1015.00 TJ based on EFC and 1312.23 TJ and 332.10 TJ based on EFL and LOW scenarios, respectively. This shows that higher energy intensity in BAU and EFL scenario is because of use of inefficient fuel like firewood. LOW scenario is the policy intervention scenario where use of electricity is preferred in the end year in all end use demands. Under this scenario, we could almost have negligible GHGs emission whereas emission projection of 2050 under BAU scenario is 7222.94 metric tonnes of CO_2 equivalent. Increasing the use of efficient technology and efficient fuel switching helps to attain the environmentally friendly energy.

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