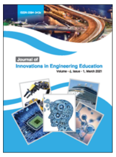

Journal of Innovations in Engineering Education
JIEE 2021, Vol. 4, Issue 2, pp 1-8.

https://doi.org/10.3126/jiee.v4i2.35007

THAPATHALI CAMPUS
Institute of Engineering
Tribhuvan University

Sustainable energy planning of residential sector: A Case Study of Bhanu Municipality

Dibya Adhikari[a,*], Shree Raj Shakya[a], Nawraj Bhattarai[a] and YP Gaire[b]

[a]*Department of Mechanical and Aerospace Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Lalitpur, Nepal*
[b]*Institute of Engineering, Central Campus, Tribhuvan University, Lalitpur, Nepal*

ARTICLE INFO

Article history:

Received 16 Feb 2021
Received in revised form 20 Mar 2021
Accepted 26 Mar 2021

Keywords:

LEAP
Energy demand
Greenhouse gases
Sustainable energy
Municipal energy planning

Abstract

Energy is the key indicator of development. Nepal is a least developed country and aims to graduate to developed country by 2022 and middle-income country by 2030 and to achieve sustainable goal by 2030. In order to achieve all these targets energy plays a key role. This research is mainly based on primary data, 152 households sample survey and supported by secondary data. Energy and emission projection was done in LEAP software based on energy demand driving factors, population growth rate and Gross Domestic Product (GDP) Growth rate. The analysis was made through different scenarios in LEAP, they are; Business as Usual Scenario (BAU), Low Carbon Emission (LOW) Scenario, Efficient Cooking Scenario (EFC) and Efficient Lighting Scenario (EFL). Analysis shows that the total annual energy consumption of Bhanu Municipality is 635.67TJ in the base year 2020 with per capita energy consumption 12.69 GJ/annum. 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 was done through grid electricity, almost 99% of the households had access to grid. The BAU scenario shows that the household energy demand per capita will be 19.07 GJ in 2050 and energy per household will be 104.56 GJ in 2050. In EFC, EFL and LOW per capita energy demand will reach to 15.31 GJ, 19.79 GJ and 4.52 GJ respectively. Greenhouse Gas (GHG) emissions for all the scenario were analyzed in the study. The GHG emission of base year was 2985.60 metric tonnes of CO_2 equivalent. The per capita GHGs emission in 2050 will be 109.08 Kg and it will be 34.28 Kg in EFC scenario and it will be reduced to zero in LOW scenario. LOW scenario shows the decrease of GHGs through the policy intervention in which electrification was done in all end use demands.

1. 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 term outcomes 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('000toe). Nepal's energy resources are

*Corresponding author:
dibyaadhikari33@gmail.com (D. Adhikari)

broadly divided into three categories: Traditional, Commercial and Alternative. Traditional energy resources include all types of biomass resources used for energy production conventionally [4], constituting 68.5% of total energy consumption, where as commercial energy resource constitutes 29.4% of total energy consumption and renewable (alternative) constitutes 2.1% of total energy consumption [5]. Total population with access to grid electricity has reached to 86% in fiscal year 2019/20 [6]. Bhanu Municipality is formed on restructuring of new Nepal by merging different VDCs. Major energy sources in the municipality are forests, water resource, agricultural residues, animal dung and solar. The census data of 2011 shows that 90.4% of households use grid electricity for lighting followed by kerosene 8.3%, Bio gas 0.3%, solar 0.1% and others 0.8%. 70.6% of total households use firewood for cooking meal, followed by bio-gas 17.1% and LPG 10.7%. Energy consumption per capita is the energy efficiency indicator in the residential sector.[7] Nepal's energy consumption per capita is 245KWh [8]. 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 [9]. 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-year vision in the fifteenth-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 and very less 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 [10]. 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. Hence, 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.

In paper [11], Shrestha et. al 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 [12] in his paper presented the benefits of low carbon and potential emission reduction taking the case of Kathmandu. In the paper [13], authors studied the energy consumption pattern and scenario analysis of residential sector of Kathmandu Valley using optimization model in MAED and MARKAL. The paper found that the urbanization has increased the energy demand. If we continue to use the same technologies and the 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 paper [14], 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 230.7TJ and 216.2 TJ respectively. Similarly, many other studies are undertaken in the field of energy analysis, this paper 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.

2. Research Methodology

The steps followed in this study were 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.

2.1. 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

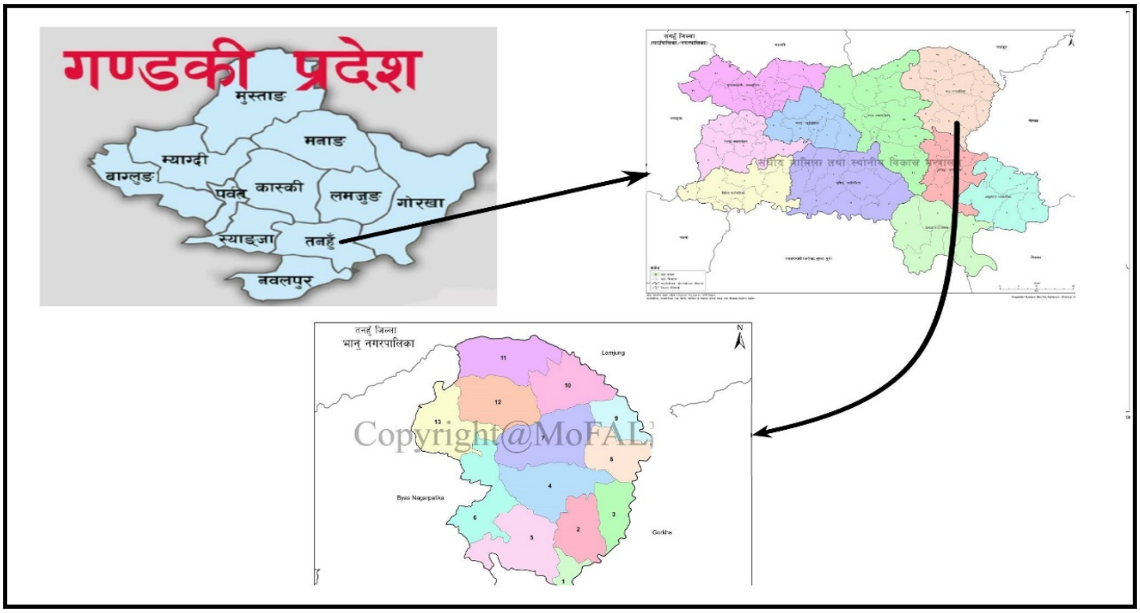

Figure 1: Location Map of Gandaki Pradesh, Tanahun district and Bhanu Municipality

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 from the census data of 2011 [15].

Table 1: Information of Bhanu Municipality

District	Bhanu Municipality
No. of wards	13
Total Area	184 Sq. Km
Population	45,792
No. of households	12,097
Household Size	3.79

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

2.2. 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 given in Eq. 1

$$S = \frac{X^2 N P(1-P)}{d^2 (N-1) + X^2 P(1-P)} \quad (1)$$

Where,

S : Required sample size

X^2 : the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841).

N : the population size

P : the population proportion (assumed to be .50)

d : the degree of accuracy expressed as a proportion (.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 the samples were 152 households. After the determination of sample size, the sample households were determined on the basis of stratified random sampling.

2.3. Selection of modeling tool

LEAP was used as a modelling tool. For this research energy demand analysis for the current year and projection of energy demand and GHG emissions need to be done up to the year 2050. Hence, the LEAP was selected for the modeling tool as it is best for mid- and long-term, bottom-up energy planning. It has several features so that the energy planning can be done easily. Energy demand projection and emission analysis was carried out in LEAP assuming the different scenario which inherits data from the current scenario by default.

2.4. 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 local alcohol, 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 was further carried out. Figure 2 shows LEAP energy demand disaggregation for Bhanu Municipality.

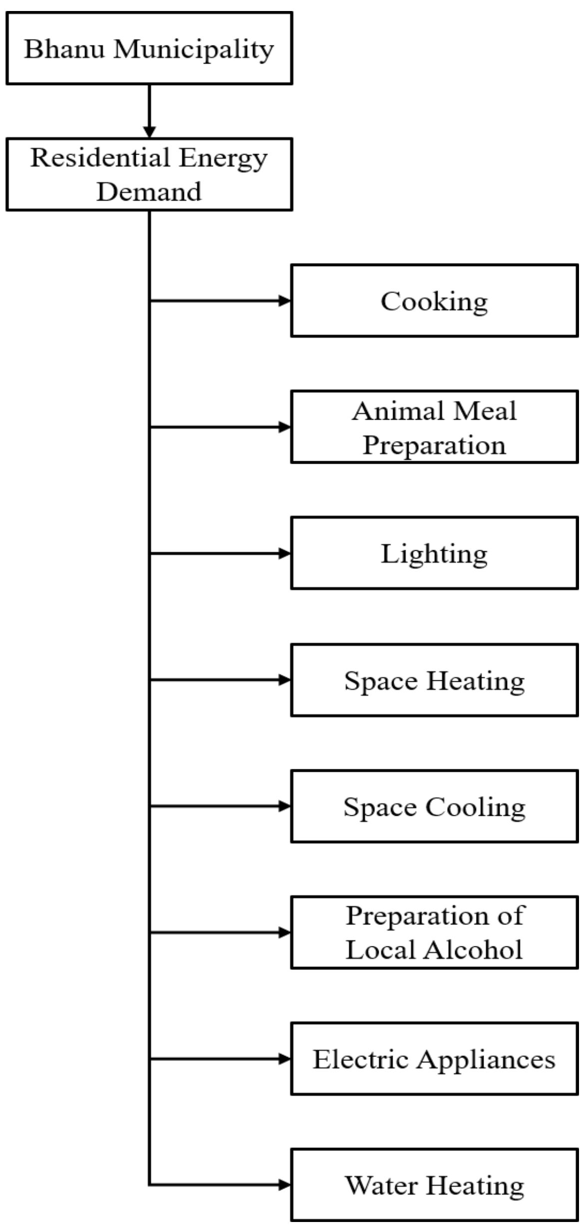

Figure 2: End use energy demand of residential sector of Bhanu Municipality

2.5. Scenario development

Scenarios were developed from the primary data survey and secondary data on demography, technologies and resources. Four different scenarios were considered in the research they are: Business-as-usual(BAU), Efficient Cooking(EFC), Efficient Lighting(EFL), Low carbon (LOW). Table 2 summarizes the assumptions of different scenarios.

3. Results and Discussions

3.1. Energy balance for base year

The base year energy balance is shown in Table 3. This shows that electricity and LPG are not produced within the Municipality, are imported outside the municipality. Wood, biogas and solar demand are met from within the Municipality. Hence, the total production of 571.45 TJ and import of 71.85 TJ has the total primary supply of 640.82 TJ. There is transmission and distribution loss of 5.15 TJ resulting in total residential demand of 635.67 TJ.

3.2. Total energy demand of base year

The total energy consumption of the residential sector of the municipality is 635.67TJ in the base year 2020 accounting for 12.69 GJ/capita. Table 4 shows the overall energy demand of the residential sector of the Municipality.

3.3. Fuel wise energy demand

The main fuels used in the municipality were firewood, LPG, electricity and biogas. Firewood shares the 89% of total energy consumption. Firewood was used mainly in cooking. People use firewood which are easily available in private or government forests and does not cost much. Firewood was utilized in maximum amount for cooking animals' 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.

3.4. End use energy demand

Cooking animal meal shares the maximum end use demand which was 257.45 TJ followed by cooking 229.43. Preparation of local alcohol had demand of 83.09 TJ, lighting had the minimum end use demand of 5.47 TJ. Water heating, space cooling, space heating and electrical appliances had the energy demand of 17.60 TJ,

Table 2: Scenario Summaries

Scenario name		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%, Traditional cook stove is replaced by ICS by 10% in end year. Limits the share of LPG to 10% in the 2030 and zero at the end year. 90% electrification in cooking by the end year.
EFL	Efficient lighting	Population Growth = 0.95%, Economic growth rate = 7%, Replacing inefficient lamps by LED with 80% share and solar PV LED by 20% share in 2030 based on national goal of SDG 7.
LOW	Low carbon emission	Population Growth = 0.94%, Economic growth rate = 7% Electrification in all end use demand by year 2050.

Table 3: Base year energy balance- TJ

Energy Balance for Area "BHANU MUNICIPALITY" Scenario: Business-As-Usual, Year: 2020, Units: Terajoule							
	Electricity	LPG	Wood	Biogas	Solar	Off-grid electricity	Total
Production	-	-	568.93	0.02	2.50	-	571.45
Imports	27.69	44.16	-	-	-	-	71.85
Exports	-	-	-	-	-	2.49	2.49
Total primary supply	27.69	44.16	568.93	0.02	2.50	2.49	640.82
Off grid electricity	-	-	-	-	2.50	2.50	-
Grid electricity	-	-	-	-	-	-	-
Transmission and distribution	-5.15	-	-	-	-	0.00	5.15
Total transformation	-5.15	-	-	-	-2.50	2.50	-5.15
Residential sector	22.54	44.16	568.93	0.02	-	0.01	635.67
Total demand	22.54	44.16	568.93	0.02	-	0.01	635.67

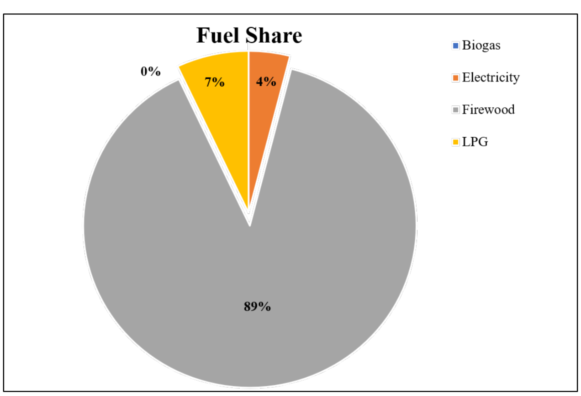

Figure 3: Fuel wise energy demand

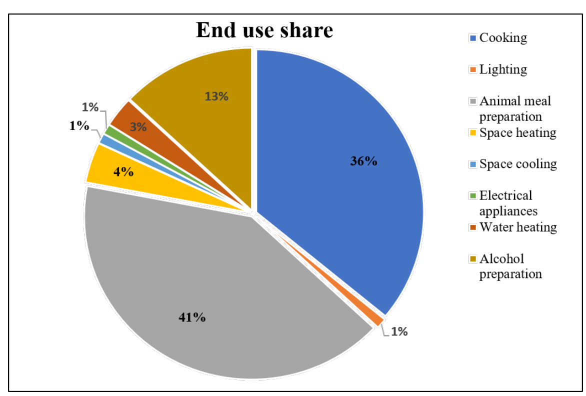

Figure 4: End use energy share

6.41 TJ, 26.44 TJ, 9.48 TJ respectively. Figure 4 shows percentage share of different end use demands.

3.5. Energy demand projection

In the LEAP different Scenarios were created based on the national and municipal targets and plans. The final energy demand projection was done under the BAU,

Table 4: Final energy demand (TJ)

End use/Fuels	Electricity	Firewood	Biogas	LPG	Solar	Total (TJ/Year)
Cooking	0.83	184.71	0.02	44.16	0.00	229.72
Lighting	5.46	0.00	0.00	0.00	0.01	5.47
Animal Meal Preparation	0.00	257.45	0.00	0.00	0.00	257.45
Space Heating	0.36	26.08	0.00	0.00	0.00	26.44
Space Cooling	6.41	0.00	0.00	0.00	0.00	6.41
Electric Appliances	9.48	0.00	0.00	0.00	0.00	9.48
Water Heating	0.00	17.6	0.00	0.00	0.00	17.6
Alcohol Preparation	0.00	83.09	0.00	0.00	0.00	83.09
Total	22.54	568.93	0.02	44.16	0.01	635.66

Table 5: Energy demand projection based on different scenario

Scenarios	2020	2025	2030	2035	2040	2045	2050
BAU	635.67	709.66	792.81	887.82	996.62	1121.15	1263
Reference	635.67	713.47	801.78	903.07	1019.77	1154.95	1310.72
EFC	635.67	641.77	642.86	716.64	801.75	900.67	1015
EFL	635.67	712.99	800.7	902.44	1019.72	1155.61	1312.23
Combined Scenario	635.67	640.32	639.65	712.50	796.50	894.13	1006.95
LOW	635.67	457.32	229.22	245.27	262.48	280.90	299.91

EFC, EFL, LOW scenarios. Table 5 shows the energy demand projection in terajoule. Final energy demand in 2050 is highest in EFL scenario which is 1312.23TJ followed by BAU 1263 TJ followed by EFC 1015TJ and LOW 299.91 TJ. The reference scenario assumes the GDP growth rate of 7% without any policy intervention. The energy projection of 2050 based on reference scenario is 1310.72 TJ. The combined scenario assumes the combined effect of EFC and EFL and has energy projection of 1006.95TJ at the end of study period.

3.6. Emission analysis

The mitigation of GHG emissions is global concern of today. Figure 5 shows the GHGs emissions for different 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 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 reduce GHG emissions to very low value by electrifying in all end use demands. This graph shows step by step replacement of conventional and fossil fuels by solar and electricity. Hence, this decreases the emission of GHGs and also local air pollutants. This decrease in GHGs and local air pollutants denotes the reduction in hazardous impact on health of living beings and environment.

Study by Rajbhandari and Nakarmi estimated that final energy demand in the year 2013 was 7500 TJ and per capita, final energy for urban and per-urban sector was 2.8 and 2.7 GJ respectively. The energy consumption per capita of Dhulikhel Municipality was 3.9 GJ per year and the final energy demand was only 72 TJ per year [13]. In this study the per capita energy consumption was found to be 12.69 GJ. The difference in per capita energy is due to the difference in study area, study period and the difference in fuels and technology used and also due to the difference in secondary data and assumptions.

4. Conclusions

Energy plays a vital role in the world economy. Residential sector energy demand has a highest energy share among other sectors. In the Bhanu Municipality Cooking animal meal is the most energy intensive end use with 41% share on total energy consumption, cooking human meal shares 38%, the firewood has the highest share in cooking followed by LPG. Use of LED light in lighting has the highest share with 44.79% followed by incandescent lamp 44.79%. The electrical appliances having high energy demand are T.V., mobile, refrigerator, water pump etc. The energy demand of firewood, solar and Biogas are met within the municipality. LPG and electricity are imported outside from the municipality. In Business as Usual (BAU) scenario, the recent trend of energy consumption was allowed to continue with the average national GDP growth of past years which is 4.8% and the municipal population growth rate of 0.94%. The final energy demand in the base year was 635.67TJ which will be increased up to 1263TJ in the 2050. The per capita energy demand in the base year

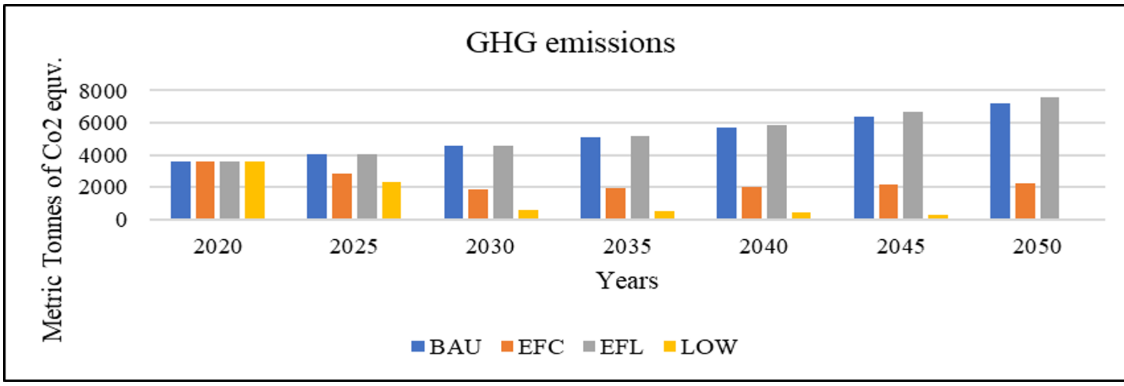

Figure 5: GHG emissions projection under different scenarios

was 12.69GJ and in the end of study year it will be 19.07 GJ. The per capita emission in the base year was 72.43 kg per capita and it will be 109.08 kg per capita in the end of study period. The total emission will be 7233.67 metric tonnes of CO_2 equivalent in 2050 which was increased value from the base year of 3627.60 metric tonnes of CO_2 equivalent. In EFC scenario the final energy demand will be 1014.99 TJ likewise in EFL scenario it will be 1312.22 TJ. The per capita emission will be reduced to 34.28 Kg in EFC scenario and the per capita energy will be 15.31 GJ. In EFL scenario the energy per household will be 108.48 GJ in 2050 and per capita energy will be 19.79 GJ. In LOW scenario, policy intervention was done in order to reduce the emission of GHG. The final energy demand will be reduced to 299.10 TJ in year 2050. The all the GHGs were reduced to 0 in 2050. The energy per household will be 24.79 GJ in 2050 and per capita energy will be 4.52 GJ in 2050. With the analysis of different scenario, it is concluded that the LOW scenario was found to be beneficial looking from every aspect i.e., energy and emission. Hence, sustainable development plan based on the LOW scenario is recommended for Bhanu Municipality by this study.

5. Acknowledgement

The authors are grateful to all the respondents of the survey, the faculty members of Mechanical and Aerospace Engineering, Institute of Engineering, Pulchowk Campus, Lalitpur, Nepal. Authors would also like to thank Stockholm Environment Institute (SEI) for providing Low Emissions Analysis Platform (LEAP) tool for free and easy access.

Conflict of interest

No conflict of interest

References

[1] Islam M A, Hasanuzzaman M, Rahim N A, et al. Global Renewable Energy-Based Electricity Generation and Smart Grid System for Energy Security[J/OL]. The Scientific World Journal, 2014, 2014: 1-13. http://www.hindawi.com/journals/tswj/2014/197136/. DOI: https://doi.org/10.1155/2014/197136.

[2] BP. Statistical Review of World Energy[R/OL]. London, England: BP, 2020: 66. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf.

[3] Chapman A, Tsuji T. Impacts of COVID-19 on a Transitioning Energy System, Society and International Cooperation[J/OL]. SSRN Electronic Journal, 2020. https://www.ssrn.com/abstract=3639283. DOI: https://doi.org/10.2139/ssrn.3639283.

[4] Gyanwali K, Bajracharya T R. Demand Side Management in Industrial Sector of Nepal[C/OL]// IOE Graduate Conference. 2013: 108-116. http://conference.ioe.edu.np/publications/ioegc2013/IOEGC-Proceedings-2013.pdf.

[5] Ministry of Finance. Economic Survey 2019 / 2020[R]. Kathmandu, Nepal: Government of Nepal, 2020.

[6] NEA. Nepal Electricity Authority, A Year in Review[R/OL]. Kathmandu, Nepal: Government of Nepal, 2020: 37-39. https://www.nea.org.np/.

[7] Energy Effic. Indic. Energy efficiency indicators[M/OL]. OECD, 2017. https://www.oecd-ilibrary.org/energy/energy-efficiency-indicators_9789264268692-en. DOI: https://doi.org/10.1787/9789264268692-en.

[8] Ramachandra B H A T, S V, Mahapatra D M, et al. Energy Situation in Nepal[R]. 2016: 128.

[9] Gaire Y P, Shakya S R. Energy and Environmental Implications of Graduating Nepal from Least Developed to Developing Country[C/OL]// IOE Grad. Conf. IOE, 2015: 112-123. DOI: https://doi.org/10.13140/RG.2.1.4556.6489.

[10] NPC. Nepal: Rapid Assessment and Gap Analysis[R]. Sustain. Energy All, 2013: 1-48.

[11] Shrestha J, Nakarmi A M. Residential Energy Consumption Pattern of a newly formed municipality : A case study of Bhojpur Municipality of Bhojpur District Introduction of Bhojpur Municipality Assessment of Energy Resources Energy Consumption[C/OL]// IOE Grad. Conf. Kathmandu, Nepal: IOE, 2014: 237-243. http://conference.ioe.edu.np.

[12] Shakya S R. Benefits of Low Carbon Development Strategies in Emerging Cities of Developing Country: a Case of Kathmandu[J/OL]. Journal of Sustainable Development of Energy, Water and Environment Systems, 2016, 4(2): 141-160. http://www.sdewes.org/jsdewes/pi2016.04.0012. DOI: https://doi.org/10.13044/j.sdewes.2016.04.0012.

[13] Rajbhandari U S, Nakarmi A M. Energy Consumption

and Scenario Analysis of Residential Sector Using Optimization Model – A Case of Kathmandu Valley[C/OL]// IOE Grad. Conf. Kathmandu, Nepal: IOE, 2014: 476-483. http://conference.ioe.edu.np/ioegc2014/papers/IOE-CONF-2014-63.pdf.

[14] Panthi B, Bhattarai N. Energy and Emission Analysis of Residential Sector: A Case Study for Reshunga Municipality in Nepal[J/OL]. Journal of Advanced College of Engineering and Management, 2018, 4: 17-27. https://www.nepjol.info/index.php/JACEM/article/view/23176. DOI: https://doi.org/10.3126/jacem.v4i0.23176.

[15] R. Municipality. District Profile of Tanahun[R].