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Sustainable Urban Household Energy Planning: A Case Study of Neelakantha Municipality, Dhading

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Abstract
This paper analyzes the present energy consumption in the household sector of Neelakantha Municipality situated in Dhading district of Province No. 3, Nepal and the energy demand upto the year of 2050. Two scenarios are used to analyze the future demands in the household sector, which are Business as usual scenario and Sustainable development scenario. The present study shows that there is 292 TJ total energy consumption per year in the household sector of Neelakantha Municipality in which the share of cooking is highest, which is 55.20%. The business as usual scenario study shows that the household energy demand will reach 958 TJ in 2050 where the major energy consumption will be 220 TJ for firewood. The sustainable development scenario shows that the household energy demand will reach only 532 TJ in 2050 where the major energy consumption will be for electricity which is seen to be almost 89% of the total household energy consumption. The environmental impacts for both scenarios are also analyzed. The study shows that the GHG emission will reach 275 kg equivalent of CO2 in 2050 in business as usual scenario whereas will be negligible for the sustainable development scenario with the improvements in energy technologies.

Keywords
Neelakantha Municipality – Household Energy Planning – Sustainable Development – GHG Emission

1. Introduction

Population growth and rapid urbanization have increased the energy demand continuously in Nepal. Around 55% of the total population of the world are belonging from the urban cities and projected to reach two-third until the year 2050. Today, 80% energy in Nepal are consumed in urban cities. Also, the emission of Carbon dioxide is higher in urban cities because of the presence of industries and a very high population [1].

The total energy consumption of Nepal raised from 106 ktoe to 650 ktoe for industrial sector and 111 ktoe to 858 ktoe for transport sector in just 20 years from 1990 to 2009. The CBS data shows that the urban GDP constitutes 33.1% of national GDP. This justifies the need for investment in urban economic development to generate the wealth and opportunities for employment boosting up the growth rate of GDP [2].

Firewood is the most dominant energy carrier, with the share of more than 70 per cent of total energy consumption in the country recently. But the use of firewood is not so efficient and pretend to be a threat to the forest of the country. Also, it causes indoor pollution in homes presenting a health hazard. The grid electricity is majorly available in urban areas, and still, around 30 per cent of the population do not have access to it [3].

According to the Nepal Electricity Authority (NEA), the consumption of electricity and the number of consumers are increasing at nearly the rate of 9% per year. The major consumption of electricity belongs to households which have raised the peak demand in the evening time dramatically. The country suffered from the shortage of power supply from 2007 to 2015, which enforced NEA to cut the power upto 18 hours per day in the major cities of the country. Because of the problem faced due to load shedding, the commercial and the industrial areas increasingly operated the expensive diesel generators and increased the imports of petroleum fuel.

NEA estimates that the energy demand will grow in the next 17 years, with an average annual rate of 8.34%. The demand for electricity is expected to

exceed 17,400 GWh by 2027 with the peak load reaching 3679 MW. This demand can only be fulfilled with the installation and operation of large hydropower in Nepal. Until now, only 1.7% of the economically feasible hydropower resources are utilized [4].

Nepal is enlisted in the list of least developing countries. The country has a population growth of 3.2% from 2010 to 2015. Due to the recent administrative reformation in the local levels of the country, the urban area has extended the boundaries from 58 urban municipalities to 293 with the increase in population share from 17% to 68%. Also, political stability and decentralized governance have increased the developmental activities in these areas [5].

The sustainable development plans for Nepal target to keep the share of biomass 30% and share of LPG 40% for the household cooking purpose in the year of 2030 with the generation of 15000 MW of electricity produced with the renewable energy sources. The per capita electricity consumption is expected to increase to 1500 kWh in 2030 [6, 7]. For the sustainable development of any town, the following paths need to be followed.

i. To perform the reduction in emission of CO2
ii. To reduce the dependence on fossil fuels
iii. To introduce the greener energy with the use of renewable energy sources
iv. To implement the efficient means for transportation with cleaner fuels

2. Energy Status in Nepal

The major consumption is limited to the household level. Still, around 25% population are below the poverty line [6]. The consumption of energy pattern of Nepal is unreliable and predominate with the traditional energy resources like biomass. The total energy consumption in the year 2011 was 10.155 million tons of oil equivalent. The traditional solid biomass comprised 86.5% of the total country's energy mix and commercial, and renewable energy sources constituted 12.8% and 0.7% respectively. The main activities leading to energy consumption in the country are cooking, lighting and heating [8].

NEA has been performing the generation, transmission and distribution for the grid electricity all over Nepal. [4]. Nepal is facing the slow development of hydropower, uncontrolled fuel import, frequent shortage of power and also the fast rise in energy demand, so that the development of affordable and efficient supply system is an essence to the energy sector of Nepal. Around 2100 MW of electricity can be produced using solar PV technology whereas 3000 MW from wind and 50 MW from micro hydros. Also, the capacity of developing 1.1 million biogas plants is possible in the domestic prevalence. [9]. The coordinating body AEPC is responsible for the promotion of renewable technologies in the remote areas and it also provides technical and financial support with different schemes of subsidy policy. Also, the foreign investment and assistance have played a good role in the installation and promotion of RETs in the country [10, 5].

3. Energy Trend in Neelakantha Municipality

This research is focused on Neelakantha Municipality, which is located in Dhading district of the hilly region in Province 3. The municipality was established in 2014 by merging the several VDCs that were Neelakantha (Dhading Besi), Sunaula Bazar, Murali Bhanjyang, Sangkosh, and further Jyamrung, Khalde and Dhuwakot VDCs were merged in 2016. Because of the remote geographical hilly areas and low economic condition, the municipality still reflects the rural lifestyle. But still, the municipality is expected to expand the commercial and industrial activities in the near future. For that, a sustainable development plan is essential. The total area of the municipality is 197.7 km2, and the population is 71,131, which is divided into 14 wards [11].

From the Municipal Profile of Neelakantha Municipality, it is seen that the major energy consumption in the Neelakantha Municipality is the traditional source of energy. Among 14,524 households, 80% of the households are using firewood as the primary energy source for cooking. LPG has been the prior source for cooking for around 17% households in the municipality. Around 96% of the households residing in the municipalities are already electrified by the power distribution line of Nepal Electricity Authority. The major consumption of the electricity is found in Ward number 3 of the municipality as the concentration of economic activities resides there. A very small number of

households are served with micro-hydropower and solar home system. The municipality has enough resources for biomass which can be accessed through the forest and agricultural activities. Also, the small resources for the hydropower generation are available inside the boundary of the municipality. For the sustainable development of the municipality, energy planning is essential, which leads to the access of clean energy to the public with modern technologies.

In the context of Neelakantha Municipality, the share of renewable energy in the energy mix of the country is very low. But due to the clean and environment-friendly technologies in renewable energy, it serves with the benefits of agricultural, economic and health concerns to the consumer. The use of Improved cookstove in the place of traditional cookstoves is reducing the use of biomass in the Municipality. The consumption of firewood can be reduced by with the use of ICS, which ultimately reduces the air pollution in the indoor. Biogas is another green energy having great probability in the Municipality with numerous advantages for health and agricultural production. It reduces the load of work for rural lifestyle for the collection of firewood from jungle. For the improvement of the system of rural energy, all three level Governments are giving priority to the production and distribution of distinct Renewable Energy Technologies (RETs) in the municipality.

From DCEP report of Dhading District, it can be observed that there are 86,067 hectares of forest in the district which comprises the main source of energy in the form of firewood. The most common commercial fuels used in the district are LPG, kerosene and electricity. Nepal Electricity Authority has been providing almost cent percent of the electricity demand in the district. It is found that the district has the high potential for the production of small scale electricity from solar, biogas and microhydros [10, 12].

The DCEP report has not provided the policy-based research for the reduction of GHG emission in the household sector. Also, the report did not provide the study about the municipal level energy consumption after the newer formation of municipal boundary after 2016.

4. Methodological Approach

4.1 Methods of Data Collection

The sample for the estimation of the current energy situation is calculated scientifically using the formula by Krejcie and Morgan (1970). This formula is particularly useful for large sample size. For the residential sector, that contains the largest study population, cluster sampling is used based on the ward wise population, and then random sampling is followed within each cluster.

$$S = \frac{\lambda^2 NP(1-P)}{\delta^2(N-1)+\lambda^2 P(1-P)} \tag{1}$$

Some secondary data are also collected. A primary database sample survey has been done from a field visit. During the visit, the focal group discussion is also done at the municipality office in the presence of Mayor Bhim Pd. Dhungana. Also, the information from Nepal Electricity Authority (NEA), Dhadingbesi, is collected as well. For primary data, 101 households are surveyed for data collection for the residential sector. And the supply information on electricity and petroleum are collected from respective offices in the municipality. Data collection for Energy Demand Assessment as well as Technology Assessment and Resource Assessment are performed using household survey.

The questionnaire is prepared so as to collect enough data to assess the present situation of energy uses as well as future wishes to change the energy technology. The questionnaire is developed in both English and Nepali language so as to make easier communication with the respondents. The questionnaire has four sections, namely: General Information of Respondents, Information on Energy Use, Information on Energy Technologies and Family Information.

4.2 Energy Demand Projections

For the projection of energy demand for the upcoming years from the base year data, Population and GDP per capita are taken as the driving variables for the final energy demand per capita. The regression for the relationship between Energy Demand per capita, Population and GDP per capita for different purpose/subsector is achieved using the following equation.

$$ESD_{i,t} = \left(\frac{POP_t}{POP_0}\right)^{\alpha i} \times \left(\frac{GDP_t}{GDP_0}\right)^{\beta i} \tag{2}$$

Where,
ESD (i,t) and ESD (i,0) = Energy Service demand per capita for sub-sector 'i' in year t and base year
POP (t) and POP (0) = Population of the municipality in year t and base year
GDP (i,t) and GDP (i,0) = GDP per capita for sub-sector 'i' in year t and base year
$\alpha i, \beta i$ = Population Elasticity and GDP elasticity

4.3 Business as Usual Scenario

It is the baseline scenario which assumes that the trend in practice is allowed to continue for the future with no intervention. For this scenario, the value of GDP growth and population growth is taken as the average GDP growth in the past years. End-use technologies are not changed in this scenario.

4.4 Sustainable Development Scenario

It follows the Sustainable development strategies of the country so as to achieve the targets of sustainable development goals. In this scenario, different interventions are carried out. The population growth is taken as the average of the past years, but the GDP growth is taken to be 7% based upon average economic growth for sustainable development of South Asia and Pacific countries. [13].

The sustainable development action plan for household targets to replace all the cooking technology into electric cooking by 2030 with the use of highly efficient induction cookstoves. The tube lights, CFLs and incandescent bulbs are to be replaced with more efficient LED bulbs with 30% of the lighting to be done from the rooftop SHS by 2030. Also, the high-income group are assumed to install large SHS ranging from the capacity of 500 to 1500 kW which can also run the small electrical appliances.

4.5 Tools used for the analysis

For this study, data collection and manipulation are performed in excel base. Long-range Energy Alternative Planning System (LEAP) software is used for the scenario analysis and forecasting of the energy demand up to 2050. [14]

5. Result Analysis and Discussion

5.1 Energy Mix for households

The overall energy mix in the household sector of Neelakantha Municipality is calculated according to the fuel and purpose. Figure 1 shows the share of energy for the different purpose and figure 2 shows the share of different fuels in the base year 2018. From these data, it is observed that the use of firewood and animal waste is still dominant with the share of 44% which is then followed by LPG whose share is 34%. The major portion of energy consumption in the household sector is found to be in cooking which is 67.3% of the total energy mix in the year 2018.

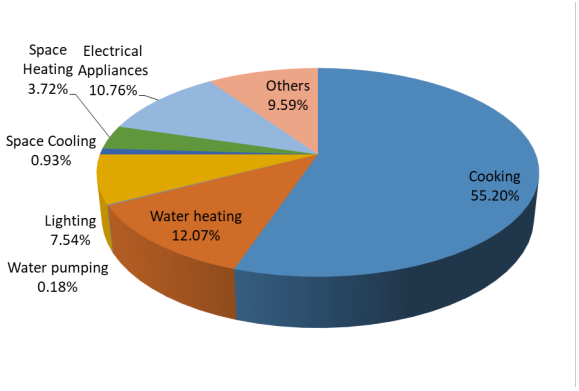

Figure 1: Energy share of different purpose - 2018

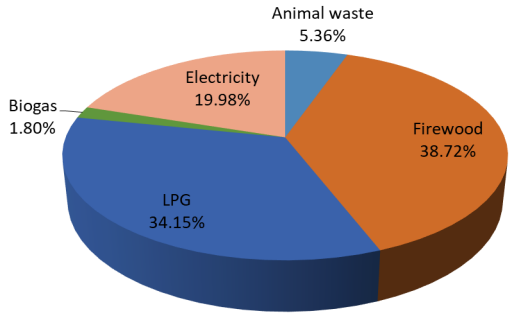

Figure 2: Energy share of different fuels - 2018

5.2 Energy balance for the base year 2018

The energy balance for the year is presented in Table 1 which shows the demand, supply and transformation of energy inside the municipal boundary. Since the wood and biomass are extracted from local resources, they are assumed to be the indigenous resource. The hydroelectricity from the national grid, though not all produced within municipality boundaries, is assumed to be indigenous production. From the DCEP report, it is seen that the energy consumed in the base year

2018 is 3,132 TJ for whole Dhading district, among which 2,916 TJ is required for cooking purpose. On comparison with this report, it is seen that around 10% of the total energy demand of the Dhading district resides only in Neelakantha Municipality [10].

Table 1: Energy balance in the base year 2018

	Electricity	LPG	Wood	Biogas	Animal Wastes	Hydro	Total
Production	-	-	**113.80**	**5.28**	**15.76**	**91.91**	**221.46**
Imports	-	**100.39**	-	-	-	-	**105.67**
Exports	**-6.14**	-	-	-	-	-	**-6.14**
Total Primary Supply	-6.14	100.39	113.80	5.28	15.76	91.91	320.98
Solar Home System	-	-	-	-	-	-	-
Grid Electricity	**78.12**	-	-	-	-	**-91.91**	**-13.79**
Transmission and Distribution	**-14.40**	-	-	-	-	-	**-14.40**
Total Transformation	63.72	-	-	-	-	-91.91	-28.18
Residential	**57.58**	**100.39**	**113.80**	**5.28**	**15.76**	-	**292.80**
Total Demand	57.58	100.39	113.80	5.28	15.76	-	292.80
Unmet Requirements	-	-	-	-	-	-	**0.00**

5.3 Energy Technologies

The technology for energy usage in the household sector is shifting to modern fuels from the traditional ones. From the survey, it is found that around 65% of the households are using LPG for cooking purpose. Around 50% of the household still use traditional cookstoves as the primary source, and around 32% use them as the secondary source. Only 6% of households are found to use grid electricity for the purpose of cooking.

After the regression analysis, the elasticities of Population and GDP for the final energy intensity for the different subsector are calculated.

Table 2: Elasticity calculations

Sub sectors	GDP Elasticity	Population Elasticity
Cooking	0.031621	3.338359
Water Heating	0.031621	3.338359
Water Pumping	0.279619	2.091975
Lighting	0.279619	2.091975
Space Cooling	0.279619	2.091975
Space Heating	0.031621	3.338359
Electrical Appliances	0.279619	2.091975
Others	0.279619	2.091975

5.4 Business as Usual Scenario

In this scenario, the recent trend is allowed to continue upto 2050 to perform the analysis. The final energy demand of the Neelakantha Municipality is expected to grow, just like the recent trend for this scenario. The final energy demand is seen to meet 438 TJ in 2030 and 958 TJ in 2050. The use of energy for different subsectors is shown in figure 3, and that for different fuel types is shown in figure 4.

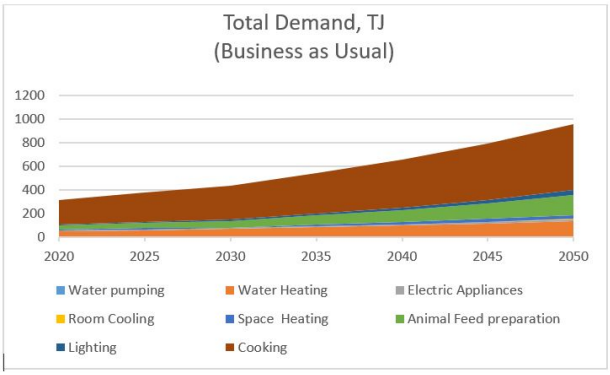

Figure 3: Demand for different subsectors - BAU

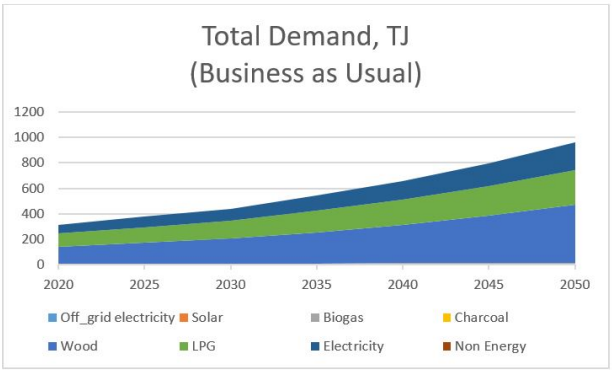

Figure 4: Demand for different fuels - BAU

The usage of different fuels for cooking purpose is shown in figure 5. It is seen that the use of firewood is dominant with the LPG and electricity following the firewood. In 2030, around 110 TJ energy is consumed in firewood whereas, in 2050, it is almost doubled to 220 TJ. The data for LPG is also seen to be nearer but slightly lesser than that for firewood.

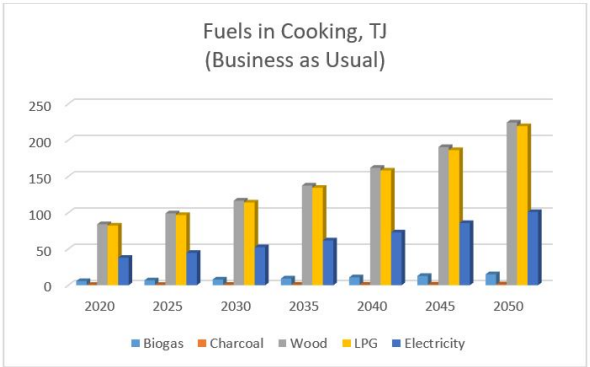

Figure 5: Fuels used in cooking - BAU

Figure 6 shows the energy for the purpose of lighting for up to 2050 for business as usual scenario. The use of CFL for lighting is found to be dominant with lesser use of LED efficient bulbs. Figure 7 shows the usage of different fuels for the preparation of food for the

animal feeding purpose. In, Neelakantha municipality, it is found that the use of electricity for the animal feeding is negligible and if the trend goes as usual, there will be no consumption of electricity for animal feeding till 2050. The use of firewood is found to reach 56 TJ in 2030 and 172 TJ in 2050.

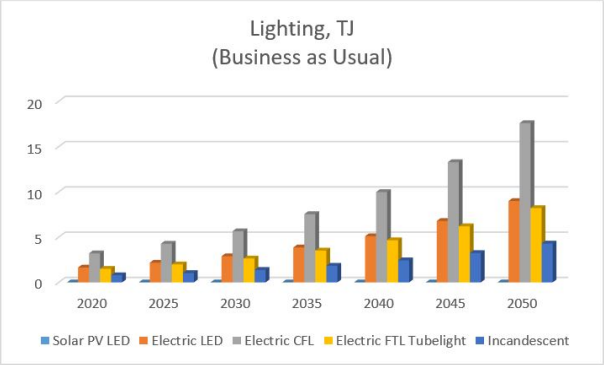

Figure 6: Lighting technologies - BAU

After the analysis of energy demand for future years, then the analysis for emission is performed. Figure 7 shows most of the household GHG emissions are observed in cooking. In business as usual scenario, the per capita GHG emission is found to be around 200 kg CO2 equivalent in 2030 and 275 kg CO2 equivalent in 2050 shown in figure 8.

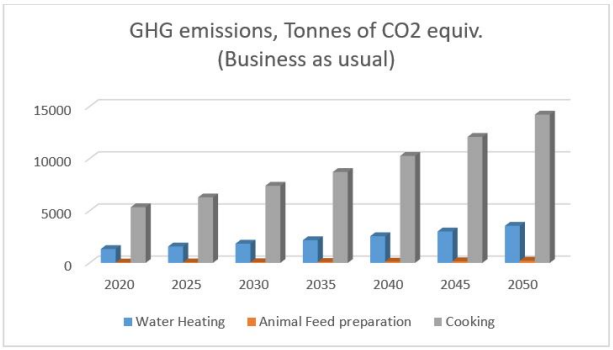

Figure 7: Subsectorwise GHG emissions - BAU

5.5 Sustainable Development Scenario

After the analysis for business as usual scenario, the various interventions are then made in the following years to develop the new scenario referred to as sustainable development scenario. In this scenario, the average GDP growth is taken to be 7% according to the sustainable development plan of South Asia. The interventions are taken according to the sustainable energy plan of Nepal. The scenario is modelled in LEAP and performed the analysis. From the results of

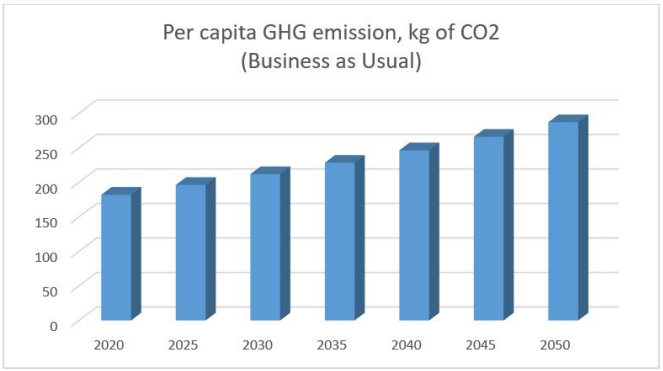

Figure 8: Per capita GHG emissions - BAU

LEAP, several graphs are then plotted. The total demand for energy was observed upto the year of 2050. The total energy consumption is predicted to decrease slightly to 290 TJ until 2030 due to the interventions and increase upto 532 TJ in 2050.

Figure 9 describes the demand for energy for different purposes for sustainable development scenario, which is found very different from the business as usual scenario. The total demand in the year 2050 for sustainable development scenario is only 55% of that of business as usual scenario. Figure 10 shows the energy demand of the following years up to 2050 for different fuels. From the figure, it is seen that after 2030, the use of electricity is highly increased leading to almost 89% of total energy consumption being electricity in 2050. The use of LPG and other traditional biomass is found to be decreasing in the following years.

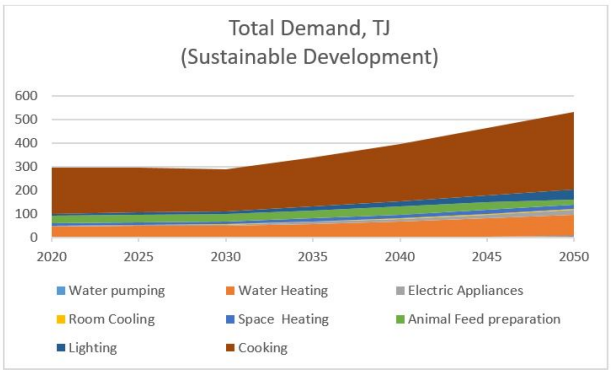

Figure 9: Demand for different subsectors - SUS

Figure 11 depicts the use of different fuels in cooking purpose for sustainable development scenario. The use of LPG and wood are found dominating before 2030, and due to extensive use of electricity in cooking after the policy intervention, the share of electricity is seen gradually increased. After 2030, the usage of LPG is

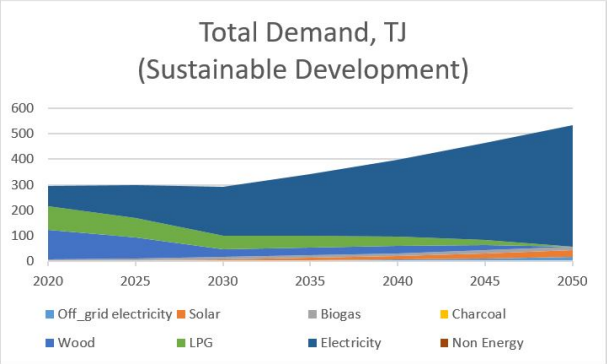

Figure 10: Demand for different fuels - SUS

dropped down, and the usage of firewood is avoided. In the years after 2030, electricity is seen to be the dominant source of energy consumption for cooking.

From the energy demand forecast carried out by Government of Nepal, Water and Commission Secretariat, it is seen that the electricity consumption will increase by around 6 times in the high economic growth than that in 2018 whereas from this research, it is concluded that the final electricity demand will increase by around 4 times in the year 2040 than that in 2018. In the report of GoN, the per capita electricity consumption is expected to be increased from 138.08 kWh in 2015 to 1536 kWh in 2040 for the BAU scenario and 2361 kWh for the reference growth scenario. But from this research, it is found that the per capita electricity consumption will reach only 567 kWh with the use of efficient technologies in the sustainable development scenario [9].

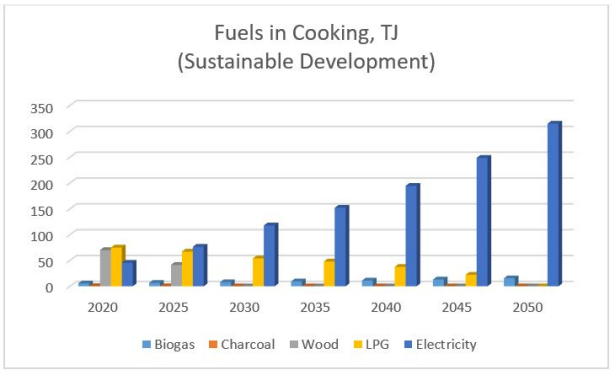

Figure 11: Fuels used in cooking - SUS

The energy consumption of different lighting apparatus for sustainable development scenario of Neelakantha Municipality is shown in Figure 12. It is seen that, for few upcoming years, the use of CFL is higher than other technologies like LED and Tubelight. But with the necessary interventions, the technologies are replaced by efficient LED bulbs. Also, after the integration of the solar home system to the households, some portion of demand is expected to meet with the Solar LEDs.

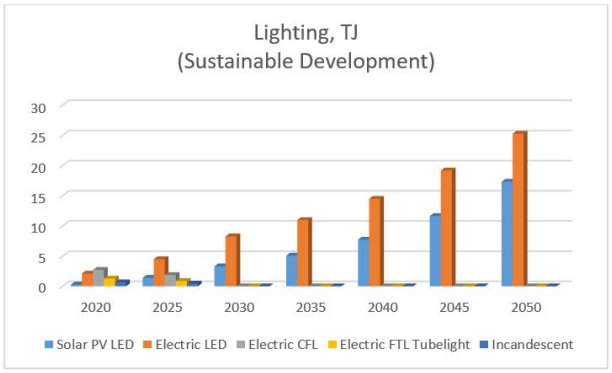

Figure 12: Lighting technologies - SUS

After the demand analysis, the analysis for emission is performed. Sustainable energy path performs the best measure to reduce GHG emissions. From figure 13, the emission is seen to be high in cooking than for other purposes. The graph shows the weight of CO2 equivalent of the GHG emissions over the following years upto 2050, as shown in figure 14.

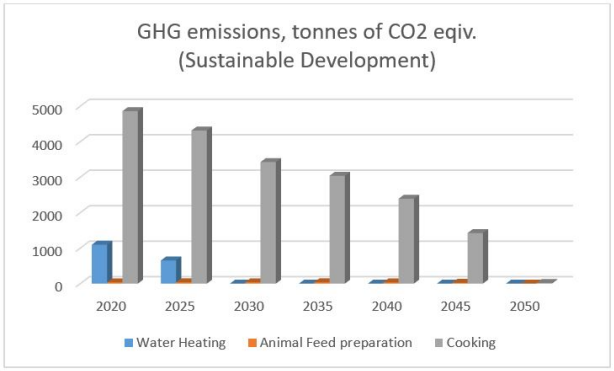

Figure 13: Subsectorwise GHG emissions - SUS

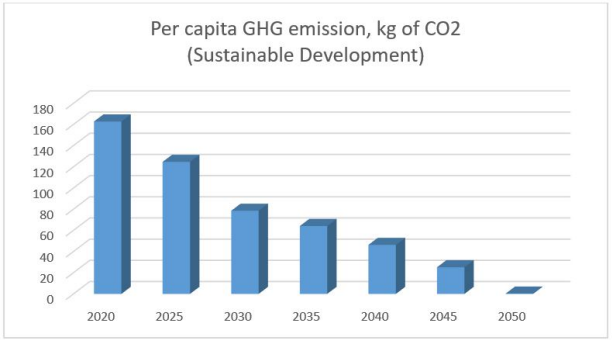

Figure 14: Per capita GHG emissions - SUS

5.6 Benefit cost Analysis

The cumulative cost and benefits for both scenarios are calculated in LEAP after providing the cost for each energy resources according to the survey. The indigenous cost of firewood is taken to be 20 NRs. per kg in the year 2018. The LPG cost is taken to be 1400 NRs. in the year 2018 per cylinder which contains 14.2 kg of LPG gas.

The discount rate of 6% is used, and the calculation for Net Present Value is achieved. From the calculations, the net present value cost for the Business as Usual scenario is found to be 34,290 million NRs. and that for the Sustainable Development scenario is found to be 32,468 million NRs, which shows that it is economically feasible to employ sustainable development policy to the Municipality.

Table 3: Cumulative cost and benefit analysis

Cumulative cost and Benefit Analysis	NPV	
	Business_as_Usual	sustainable development
Demand	2114.51	7156.01
Residential sector	2114.51	7156.01
Transformation	874.56	2452.5
Transmission and Distribution	-	-
Grid electricity	874.56	2394.79
Off_grid electricity	0	57.7
Resources	11229.34	2827.7
Production	7907.26	1495.64
Imports	3322.08	1332.06
Exports	-	-
Unmet Requirements	-	-
Environmental Externalities	72.32	32.52
Non Energy Sector Costs	-	-
Net Present Value	14290.74	12468.73
GHG Emissions (Mill Tonnes CO2e)	0.37	0.11

6. Conclusions and final remarks

With the implementation of the sustainable development plan, the total energy consumption in the year 2050 is found to be reduced to 532 TJ which is less in comparison to Business as Usual plan for which the total energy consumption is 958 TJ. This large reduction in the use of energy is beneficial as the energy could be used for industrial purposes in the municipality. The GHG emission of 17994 tonnes of CO2 equivalent in the year 2050 in business as usual scenario is seen to be negligible for sustainable development scenario because of the use of all efficient and non-emissive technologies.

From the cumulative cost-benefit analysis of both scenarios, it can be concluded that it is beneficial to employ the sustainable development plan in Neelakantha municipality as the Net Present value Cost of Sustainable Development Scenario is found to be lesser than that of Business as usual scenario. In this way, the policy intervention for sustainable development is concluded to be beneficial in all aspects. i.e. Demand aspects, Emission aspects and Economic aspects. Hence, the sustainable development plan for Neelakantha Municipality is recommended by this study.

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