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Sustainable Energy Planning and Electrification for Urban Households: A Case Study of Neelakantha Municipality, Dhading, Nepal

by

Sagun Paudyal

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The undersigned certify that they have read and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Sustainable Energy Planning and Electrification for Urban Households: A Case Study of Neelakantha Municipality, Dhading, Nepal**" submitted by Mr. Sagun Paudyal in partial fulfillment of the requirements for the degree of Master of Science in Renewable Energy Engineering.

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ABSTRACT

This study targets to perform the analysis of consumption of energy in the present situation in the residential sector of Neelakantha Municipality situated in Dhading District of Bagmati Province, Nepal. This study also performs the energy demand forecasting for the municipality from the year 2020 to the year of 2050. In this study, two basic scenarios are employed for analyzing the future energy demands in the household sector of Neelakantha Municipality namely: Business as Usual Scenario and Sustainable Development Scenario. The scenarios are developed and detailed analysis is performed in Low Emission Analysis Platfrom (LEAP) software.

First of all, the detailed analysis for the current household energy situation of Neelakantha municipality is carried out through the sample survey in the households of the municipality. Among 14,524 households, a sample size of 101 households are selected which are divided proportionally according to the population of each ward. The study of the present situation shows that there is total energy consumption of 292 TJ per year in the household sector of Neelakantha Municipality which comprises 4.11 GJ per capita per year. The share of energy is seen to be for the cooking purpose which constitutes 67.3% in the total consumption. For the cooking purpose itself, the firewood constitutes 40.01% and LPG constitutes 39.13% share which are the most dominant sources for the municipality.

The Business as Usual Scenario (BAU) shows that the demand of household energy will reach 13.48 GJ per capita per year in 2050 where the sum of firewood energy consumption for household will reach 47.25%. Similarly, the total consumption of LPG will reach 28.6%. The share of electricity covers only 22.44% of total energy consumption in 2050 with the per capita electricity consumption of 840.16 KWh annually.

In the same way, the Sustainable Development Scenario (SUS) shows that with the interventions of the modern energy technologies, the total energy demand of households will reach only 7.48 GJ per capita in 2050. At that time, the major energy consumption will change to electricity which constitute 474 TJ of energy share out of 532 TJ which is approximately 89% of total consumption of energy. The electricity consumption reaches 1851.79 kWh per capita annually. The use of LPG and firewood will be diminished

drastically by 2050 with the proper modification in the technologies used for different household purposes.

The GHG emissions for both the scenario are also analyzed in this study. The study shows that the of GHG emissions will reach 17,994 tonnes of CO_2 equivalent in 2050 which is 275 kg equivalent of CO_2 per capita in Business as Usual Scenario. But for the Sustainable Development scenario, the GHG emission in cooking will be 19.2 tonnes of CO_2 equivalent only with the replacement of cooking technologies with the cleaner technologies such as electric cookers with negligible emissions. It will reduce the emission by 62.82% in 2030 and 99.89% in 2050 from the values of emission in the Business as Usual Scenario.

At last, the cumulative cost and benefit analysis is carried out for both the scenarios. Taking 6% as the social discounting rate for the net present value calculation, the cost benefit analysis up to the year 2050 is analyzed. For the Business as Usual scenario, the net present value of cost is calculated to be 14,290 million Nepali Rupees and that for the Sustainable Development scenarios is calculated to be 12,468 million Nepali Rupees, thus reducing the total cost by 1,822 Million Nepali rupees until 2050.

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Sagun Paudyal

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LIST OF ABBREVIATIONS

AEPC	Alternative Energy Promotion Center
BAU	Business as Usual
CBS	Central Bureau of Statistics
CFL	Compact Fluorescent Lamp
CO_2	Carbon Dioxide
CRT TV	Cathode Ray Tube Television
DOS	Department of Survey
DOTM	Department of Transport Management
ESAP	Energy Sector Assistance Program
ESD	Energy Service Demand
GDP	Gross Domestic Product
GHG	Greenhouse gas
GJ	Gigajoule
ICS	Improved Cook stove
IEA	International Energy Agency
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilo Watt Hours
LEAP	Low Emission Analysis Platform
LED	Light Emitting Diode
LEDS	Low Emission Development Strategies

LPG	Liquefied Petroleum Gas
MOEWRI	Ministry of Energy, Water Resources and Irrigation
MOF	Ministry of Finance
NEA	Nepal Electricity Authority
NRs.	Nepali Rupees
NPC	National Planning Commission
PJ	Peta Joule
PM	Particulate Matter
RERL	Renewable Energy for Rural Livelihood
RET	Renewable Energy Technology
SEI	Stockholm Environment Institute
SUDP	Sustainable Urban Development Planning
SUS	Sustainable Development
TJ	Tera Joule
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
USD	United States Dollar
VDC	Village Development Committee
WBG	World Bank Group
WECS	Water and Energy Commission Secretariat
WHO	World Health Organization

CHAPTER ONE: INTRODUCTION

1.1. Background

The energy consumption and demand of Nepal has been increasing continuously with the population growth of the city area and rapid urbanization. Among the total population of the world, around 55% belong to the urban cities and this urbanization is projected to reach two-third by the year 2050. Today, 80% energy of the world is consumed in urban cities where the industries are centralized. The amount of emission of Carbon dioxide gas in urban cities is also higher because of very high population, higher transportation facilities and the higher number of industries (UNFPA, 2017).

Although there are some small potential deposits, there are no commercial reserves for coal, oil or gas in Nepal. The major primary sources used in the country for the energy are solid biomass, electricity, coal, oil, LPG and hydropower. Solid biomass is the leading energy source in the country which is used in the form of firewood, animal wastes and agricultural wastes because the alternating energy resources are still lacking. The vital consumption of energy is found to be in the household sector. The portion of energy in the transport and industrial sector are little till now but expected to grow very fast.

Nepal Oil Corporation is an enterprise owned by federal government of Nepal which is importing the oil products from its neighboring country India. The LPG gas import in the fiscal year 2017/18 was 2.07 million kilo liters and it is increasing with the rate of 13.8% each year. The LPG storage capacity of Nepal is only 71,622 kilolitres which can serve for only 15 days. The diesel and petrol are the other petroleum products which are being imported for transportation purpose. Around 950 MW of electricity is produced in Nepal but still 200 to 250 MW is imported from India to serve the demand of 1300 MW. This validates the need for economic investment for the development of urban areas to generate the wealth which also creates the opportunities for employment enhancing up the GDP growth rate of Nepal (MOF, 2019).

Nepal’s economic development has been a complicated scenario because of the very unstable political changes in recent years from the royal monarchy to the federal republic. The data shows that 33.1% of the national GDP of Nepal is constituted by the urban GDP in Nepal. 67% of the population and 33% of the GDP of the country relies on the agriculture sector (MOUD, 2017). Nepal arrived in the modern era only after the 1950s with very little number of schools, roads, hospitals, telecommunications, electricity and industries. After then, Nepal has made sequential progress towards sustainable economic growth.

Nepal has been implementing the series of five-year plans in an effort to make the progress in enhancing the economic status. Government has been prioritizing the development of infrastructures for transportation, communication facilities, industries and agriculture over the years. Since 1975, the improvement in government administration and the efforts in rural development have been emphasized (NPC, 2019).

From the economic survey of Nepal conducted on 2018/19, the total energy consumption of Nepal was 9,212 tonnes of oil equivalent where the share of traditional, commercial and renewable energies for the year was 68.6%, 28.2% and 3.2% respectively. This shows that the renewable energies are not yet harnessed in significant way in Nepal (MOF, 2019).

In Nepal, the most dominant energy carrier resource is firewood which share above 70 percent of the final energy consumption of the whole country. But these firewoods are not much efficient and the uncontrolled deforestation is also being the threat for the country. These firewoods are also responsible to create the indoor pollution in homes and also responsible for some kinds of health hazards. The electricity from the national grid is majorly available 90% of the urban areas, but around 30 per cent population, majorly from the rural areas of the country still do not have electricity access (CBS 2011).

With the increment in the consumption of electricity and the number of consumers nearly at the rate of 9 % per year, the major consumption is in households has raised up the peak demand dramatically at the time after 6 pm to 10 pm. The shortage of electricity supply suffered the country since 2007 to 2015, which enforced NEA to schedule the cut off of the power for upto 18 hours per day in city areas of the country. In those years, the commercial and the industrial sectors had to operate the expensive diesel generators which increased the imports of petroleum from India because of the problem faced due to load shedding. But with the proper load balance management and import of electricity from India, this problem has been eliminated (NEA, 2019).

Nepal Electricity Auuthority estimates that the energy demand will increase with average yearly rate of 8.34% in the following 17 years. The electricity demand is expected to meet 17,400 GWh in the year 2027 with the peak load at the evening time reaching 3679 MW. For the fulfillment of this peak demand, the installation of large sized storage hydropower stations are essential. Although the economically feasible hydropower capacity of Nepal is 42,000 MW, only 1.7% hydropower resources that are economically feasible are utilized until now (NEA, 2019).

Nepal is still enlisted in the list of least developed countries. The population of Nepal has annual growth of 3.2% in previous 10 years. As the number of municipalities in Nepal extended from 58 to 293, the urban population has drastically raised to 68% from 17% with the recent administrative reform of the country after the establishment of federal system in Nepal. Also, political stability and decentralized governance in the local levels municipalities increased the activities of development in these regions. Urban growth has brought social and economic changes. Side by side, it also increased air pollution with the uncontrolled growth of inefficient transportation and industries.

It is planned to limit the share of biomass to 30% and share of LPG to 40% for the purpose of cooking in the household sector of Nepal in the year 2030 according to the sustainable development plans of Nepal. Also, it is planned that the production of 15,000 MW of the electricity in the year 2030 with the renewable energy sources will increase the electricity consumption to 1500 kWh per capita annually (MOEWRI 2018; NPC 2017). The paths that are needed to be followed for the sustainable development of any city are as listed below:

i. The emission of CO_2 has to be reduced.
ii. The dependence on the imported petroleum has to be reduced.
iii. The electrified technologies have to be used to replace the conventional inefficient technologies.
iv. The efficient means with the use of clean fuels should be implemented in the transport sector.

1.2. Problem Statements

The recent modification in the administrative boundaries of the local level has increased the population of urban areas from 17.1% designated in 58 municipalities in 2011 census to 293 municipalities in 2017 which concentrates 40% of the country's population. It is found that over the half of the urban populations resides in Kathmandu valley, Pokhara valley and the cities in Terai (MOUD, 2017). Even though there were studies of energy consumptions in the district level, there were only limited energy studies for the local levels.

The geography of Nepal recommends that the hydropower generation has a lot of probabilities in the country, due to the high gradient terrain, river coming from the Himalayas and the monsoon rains. Still, the community forests are the primary energy sources which are providing the source of firewood.

The problems related to the energy sector of the country are determined by the following elements:

i. The use of imported petroleum products has put the burden on the economy of the country.
ii. The depletion of the forests for firewood may lead to unbalance in the ecology.
iii. The large hydropower installation and operation is high capital consuming and have a long period for return.

1.3. Justification of Research

Nepal is expected to meet the targets of sustainable development to upgrade from the list of least developed countries to the developing country in 2030. The economic activities need to be boosted up with the large utilization of available resources with less carbon emission. The Ministry of Urban Development has formulated the Strategy for National Urban Development to provide the cent percent access to the reliable supply of electricity using cleaner energy sources like hydropower and solar photovoltaics (MOUD, 2017).

This research is carried out on Neelakantha Municipality (Figure 1.1), situated in Dhading district, which totally lies on the hilly region in Bagmati Province of Nepal. The municipality was established in 2014 with the merger of the several VDCs that were Neelakantha (Dhading Besi), Sunaula Bazar, Murali Bhanjyang, Sangkosh, and further Jyamrung, Khalde and Dhuwakot VDCs were merged in 2016. As the municipality has very remote geographical hilly areas where the low people have very low economic condition, the lifestyle of the municipality is still similar to the remote regions of Nepal. The total area of the municipality calculated from the map is 197.7 km^2 and the total population is 71,131 (Municipality Profile). The municipality is divided into 14 wards.

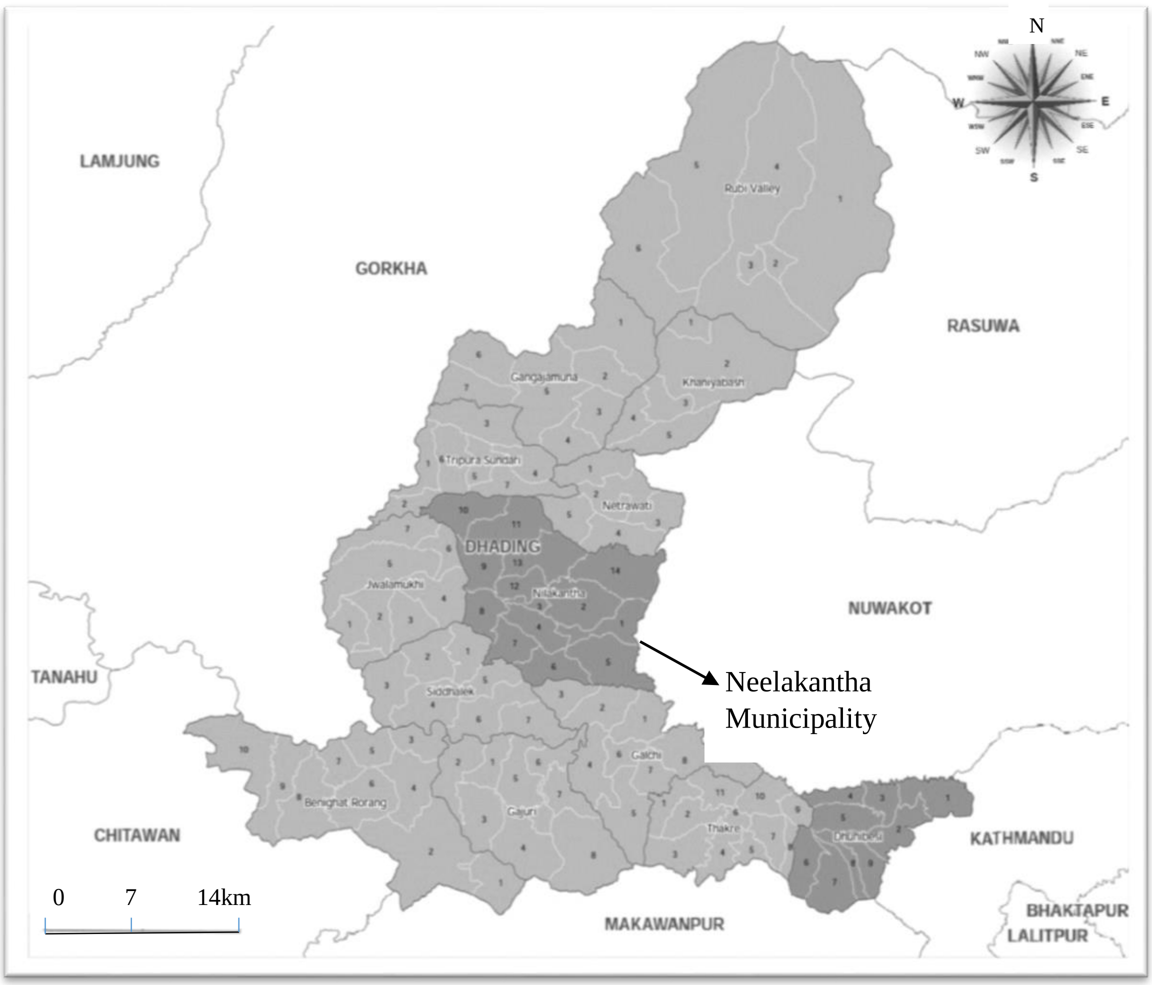

Figure 1.1 Location of Neelakantha Municipality in Dhading district (Source: DOS, Nepal)

The traditional biomass is the source for major energy consumption in Neelakantha Municipality. Around 80% of the households still use traditional cook stoves and secondarily a few use LPG stoves. Around 80% of the households are served through the grid electricity. Only very small number of households are supplied with micro-hydropower and solar home system in the Municipality. The resources for the biomass is enough inside the municipality which can easily be retrieved from the community forest and own fields through agricultural activities. The small hydropower resources are available inside the periphery of the municipality. The proper energy planning for the municipality is necessary for the sustainable development so as to provide the clean energy access to the public of the municipality with the modern efficient technologies.

The Constitution of Nepal provides the authority of the development of small hydropower projects and the production of alternative energy through various renewable energy sources such as Wind, Solar and Biogas. This provision is enlisted in the 19^{th} number of the list of Powers of Local Level Government in the Schedule 8 of the Constitution of Nepal linking to the clause 4 of Article 57. (Constitution Assembly, 2015)

1.4. Objectives

1.4.1 Main Objective

The primary aim of this study is to study the sustainable energy planning for future years up to 2050 for households of Neelakantha Municipality.

1.4.2 Specific Objectives

i. To prepare the baseline household energy situation of Neelakantha Municipality for the current year
ii. To analyze the future energy demand according to business as usual scenario
iii. To evaluate the opportunities for the electrification in household energy uses which are appropriate for the Sustainable development
iv. To conclude the best scenario among Business as usual scenario and sustainable development scenario for different aspects

1.5. Limitations to the Research

The key limitations regarding to this research are:

i. The survey for this research is carried out with the cluster sampling on each ward according to their population. The further classifications of the households of the municipality according to the cast and classes are not carried out.
ii. Some of the villages of the municipalities are in the distance to travel more than 12 hours by foot so that every village are not included in the part of the survey.
iii. Since all the economic constraints for the municipal levels are not available, the national values are taken into considerations.

CHAPTER TWO: LITERATURE REVIEW

2.1. Sustainable Urban Development planning

In the last 25 years, the migration to the urban cities has been observed so dramatically increased so that around half of the total population in the world residents in the city area. There is high urbanization of around 78% in Latin America and Caribbean. Asia and Africa are comparatively less urbanized that is only 40% of the total populations are recently in urban areas. According to the forecasting of population division of United Nations, around 89% population of Caribbean and Latin America and around 62% population of Asia and Africa will resident on the urban areas with concentrated population growth only in city areas. Along with bigger cities, the smaller urban areas are also developing, and the population is migrating to those areas too (UN, 2019). The preparation of action plan for the sustainable energy development of any city is essential due to the following advantages:

New job opportunities – The replacement of inefficient energy system with the modern, efficient technology represents the opportunity of high investment which in order create new opportunities for employment. The reduction in expenses of energy management can be spent on other development activities.

Financial Savings – The saving of money is essential for the local level government. By improving the efficiency in municipal energy consumption, many operating costs can be reduced.

Improvement in local air quality – With the efficient use of energy management and the modification with cleaner technologies, the emission and pollution of air are reduced which can cause a severe health hazard and environmental problems.

New Partnership – The private sector and public sectors are showing the interests in energy management for different reasons. With the new programs of Renewable energy integration, the coordination between the utilities, financial institutions, local government and private organizations take place.

Local Economic Development – The proper management of energy usage drives the promotion of modern, efficient systems according to the resources available in the boundary which is a path to the development of the local level.

The urban design was initiated with the fundamental purpose of beautification of the city but the objectives of urban design were changed over time. The activities in urban area increased the negative environmental impacts with the degradation of natural resources and climate change. It is essential to conduct the ecological planning for the urban areas so that the available natural resources are consumed in sustainable as well as efficient way. A study was carried out about the necessity of the application of ecological planning under the sustainable urban development (Mersal, 2016).

The faster rate of global urbanization is increasing the energy consumption primarily from the fossil fuels. But they are causing the environmental impacts which is conflicting with the sustainable development goals described in UNDP. The usage of sources of renewable energy cannot replace the consumption of fossil fuels with the clean energy technologies totally till 2030. Since the ultimate aim is to reduce the poverty, many countries have been practicing different models for urban planning. China has used the vertical model to reduce the poverty with the increase in consumption of renewable energy resources. Similarly, Sweden has chosen the horizontal models of planning with the involvement of actors under local level (Wennersten, 2018).

Sustainable Energy for All (SEforALL), which is an UNDP Programme, has been working leading the civil societies, private sectors and governments for the achievement of the goals listed on SDG7. The SDG7 calls the sustainable energy access to whole world population until the year of 2030. The SDG7 also supports the Paris agreement to minimize the GHG emissions for limiting the global warming under 2 degree Celsius. The affordability, reliability and sustainability are the three major focuses of the SDG7. It is responsible to progress the health status and lifestyles of the billions of the population in the world with confirming the access of modern, clean and sustainable energy resources. The World Bank Group has been investing a large amount of money for the major target regions of energy access, renewable energy and energy efficiency (WBG, 2019).

2.2. Background of Energy Situation in Nepal

Nepal is enlisted in the list of least developed countries where still 83% of the total people in the country are living in a rural lifestyle according to the census conducted in 2011 (CBS, 2011). Agriculture sector constitutes around 33% of the total GDP of Nepal (MOF, 2019).

The major consumption of energy in Nepal is limited to the residential sector. Around 25% population of Nepal are still below the line of poverty (NPC, 2017). The pattern of energy usage in Nepal is predominate with the conventional energy sources like biomass (WECS, 2014). The 68.6% of the total energy mix of Nepal is comprised with traditional solid biomass. The commercial energy sources and renewable energy sources constituted 28.2% and 3.2% respectively of the total national consumption of energy (MOF, 2019). The total consumption of energy in Nepal in the year 2017 was 544.28 PJ (Bhusal and Nakarmi, 2019).

Among 42000 MW of technically feasible hydropower potential, only 2.5% has been harnessed. The big storage projects such as Upper Tamakoshi, Madhye Bhotekoshi, Upper Trishuli are under the phase of completion. Nepal Electricity Authority had to face a extreme shedding of power upto 18 hours in the year 2012 due to lack of electricity supply. But after 2016, this problem has eliminated with the proper load supply management from NEA. According to the forecast of NEA, the annual peak electricity demand will reach 3679 MW in the year 2027 (NEA, 2019).

The consumption of energy in the household sector has a high proportion in Nepal whereas it is found to be in industrial areas in most of the developed countries. Firewood, agricultural wastes and animal dungs are the major energy sources for household energy consumption. The major activities responsible for consumption of energy resources in the country are cooking, water heating, space heating and lighting (WECS, 2014).

2.3. Renewable Energy Status in Nepal

According to the White Paper published by Ministry of Energy, Water Resources and Irrigation, more than 2,000 small and medium industries are established with the productive use of renewable energy in Nepal. The 4,00,432 household biogas plants, 88 mega biogas plants, 7,94,276 solar home systems and 1,701 institutional solar photovoltaic systems are producing electricity in the country. 29,457 KW of electricity has been harnessed through Micro hydro power stations and 413 KW has been harnessed through Solar Wind Mini Grid Systems (MOEWRI, 2018). NEA has been involved in the activities of generation, transmission and distribution of the electric power all over Nepal through the national grid (NEA, 2019). Nepal is facing the problems of very slow development of hydropower, uncontrolled import of petroleum fuel, frequent electricity shortage and also the fast escalation in demand of energy. It is necessary to develop the efficient as well as affordable supply system to the energy sector of Nepal (K.C. et al., 2011; Nepal, 2012). For the improvement of the energy system in rural areas, the Government of Nepal has given priority to the production as well as distribution of distinct Renewable Energy Technologies (RETs) including biomass, biogas, solar and micro-hydro (Katuwal and Bohara, 2009). Almost 2100 MW of electricity can be harnessed through solar photovoltaic technology and almost 30000 MW of electricity can be harnessed through wind energy conversion technologies. Also, 50 MW of electric power can be harnessed from the installation of micro hydro power stations and 1.1 million plants of biogas can be installed in the domestic prevalence of Nepal (WECS, 2014). AEPC is the governmental body responsible for the promotion of technologies for renewable energy in the remote places of Nepal. AEPC has also been providing the technical and financial supports to the public with various schemes and subsidy policies. In Nepal, the investment and assistance from the foreign donors have also played a respectable role in the promotion as well as installation of Renewable energy technologies in the country (AEPC, 2017). The Biomass serves the 72% of the final energy usage of Nepal. The use of petroleum products such as LPG, Diesel and Petrol have the demand share of 14%. The usage of electricity and renewable energies are still very low compared to the use of biomass and petroleum products as shown in figure 2.1 (MOF, 2019).

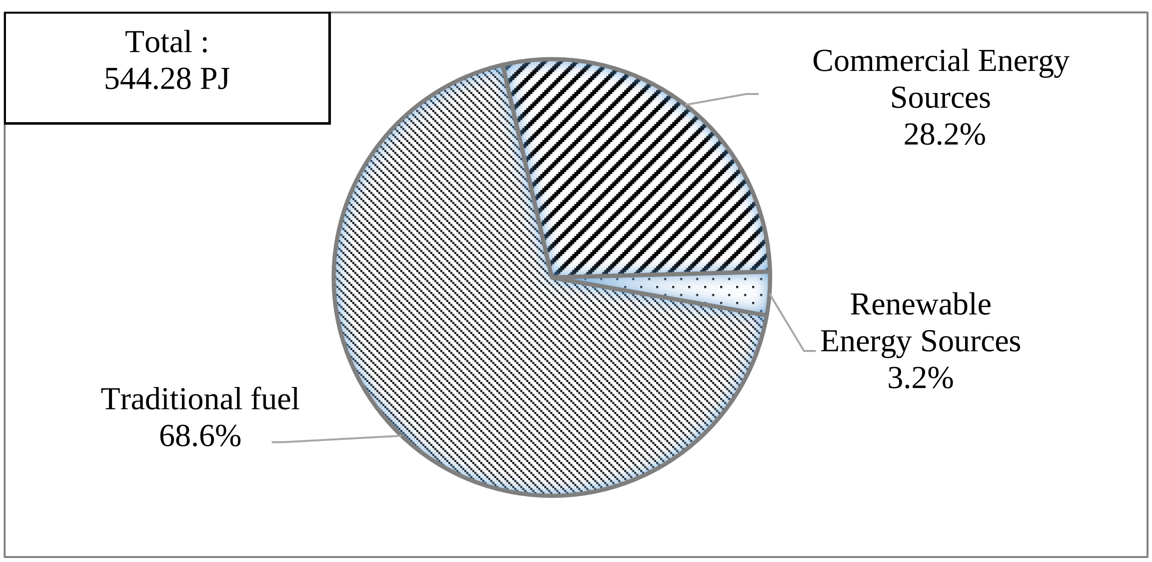

Figure 2.1 Energy Supply mix of Nepal in 2017 (MOF, 2019)

Figure 2.2 shows the share of energy usage in different economic sectors of Nepal in the year 2017. Because of the very poor industrialization in Nepal, the major demand relies in the residential sector which is around three fourth of the total demand. The remaining one fourth of the total demand belongs to the Industrial, Transportation, Commercial and Agriculture sector (MOF,2019).

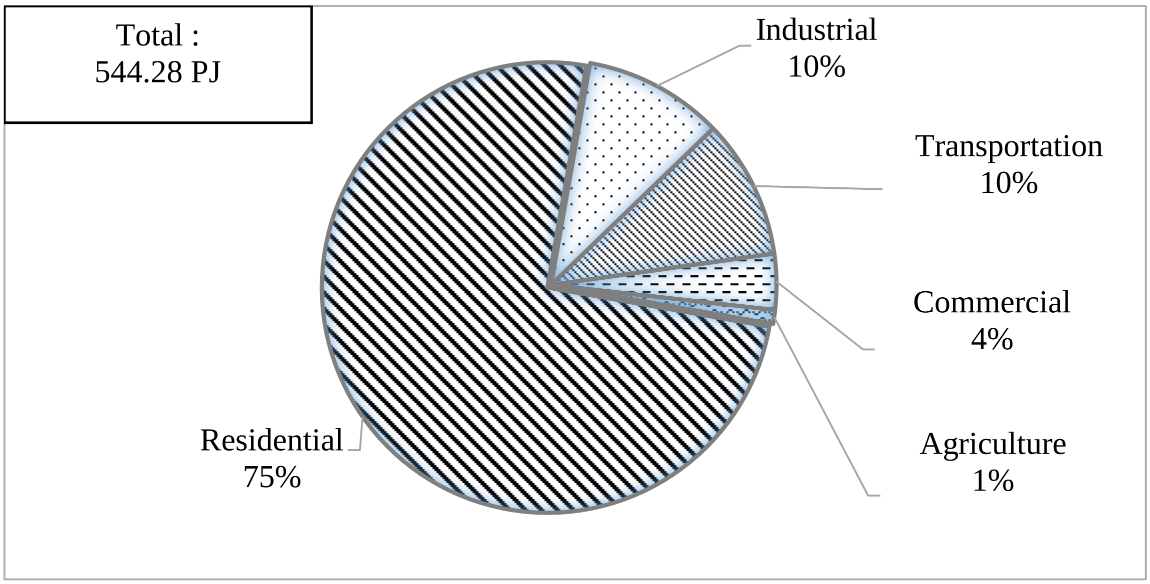

Figure 2.2 Energy Consumption for different fuels in 2017 (MOF, 2019)

The share of energy consumption, according to the different provinces of Nepal is shown in Figure 2.3. Since the federal capital of Nepal lies in Bagmati Province, its energy consumption is higher in compared to other provinces. The energy consumption of Karnali Province and Sudur Paschim Provinces are only 3% and 9% of the total consumption of the country which reflects the poverty of the residents within these provinces (Bhusal and Nakarmi, 2019).

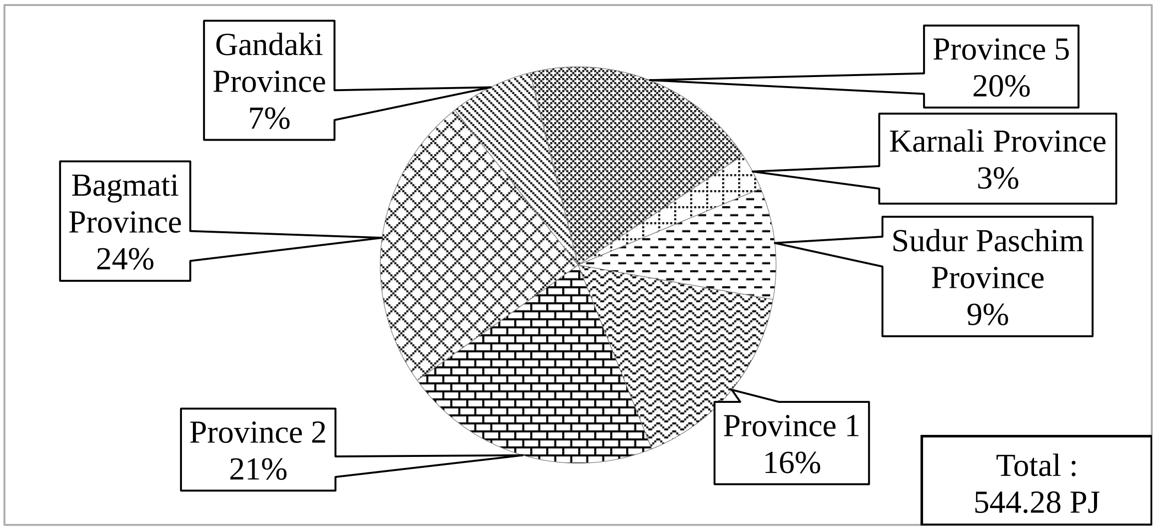

Figure 2.3 Share of consumption of energy in the provinces of Nepal in 2017 (Bhusal and Nakarmi, 2019)

2.4. Advantages of renewable energy in Nepal

In the context of Nepal, the portion of renewable energy in the energy mix of the country is around 3.2% which is still very low. The clean and emission-free technologies in renewable energy can provide the benefits on the agricultural, health concerns as well as economic concerns to the consumer side (Katuwal and Bohara, 2009). The efficiency of the traditional cookstoves is very low in the range of 5% to 10% whereas that of Improved cook stove is 25% to 30% (Pokharel, 2003). The firewood consumption can be minimized by 50% with the use of Improved Cooking Stove (ICS) which eventually reduces the indoor air pollution by 80%. Annually, 420 tonnes of biomass can be saved using the ICS which can reduce the deforestation of 262 hectors of jungle along with the reduction in GHG emission by 1.2 tonnes of CO_2 equivalent per year (Sapkota et al. 2012). Biogas is another green energy with various benefits for the agricultural production and the health concerns. It also decreases the load of work to the public for the collection of firewood from community forest. (Katuwal and Bohara, 2009). The implementation of biogas technology in the rural lifestyle can conserve about 14,268 tonnes of firewood every year which prevents the deforestation of 8,917 hectares of forest area along with the reduction in carbon emission (Sapkota et al., 2012). Micro hydropower and solar PV technology are popular for Nepal. Micro hydropower installation reduces the consumption of conventional energy resources and imported fuels (Gurung, 2011).

2.5. National Planning for Sustainable Development Goals

The target of the Sustainable Development of Nepal includes ending the poverty, hunger and malnutrition, ending the preventable newborns, ending the gender discriminations and ending the deprivation of the basic facilities such as sanitation, clean drinking water and modern energies. For the sustainable development of Nepal, the three sectors: clean energy, tourism and agriculture are primarily concerned. Nepal has the potential to encounter all the demand of energy across the country through the hydroelectricity. Over the next decade, around 10,000 MW of electricity will be produced through the hydropower plants which are now under construction phase. This amount of electricity production will eliminate the power cuts, distribute electricity to the 100 percent population over the country and also will reduce the pollution with the replacement of non-efficient and emissive technologies in the energy consumption. National Planning Commission is following the National Monitoring and Evaluation Guidelines and promoting the policy environment for the tracking and evaluation of the Sustainable Development Goals. Nepal Planning Commission has been shifting gradually from the narrow monitoring to the monitoring and evaluation based on results. Before the formation of the provincial bodies, the monitoring and devaluation were carried out through regional directorates and regional administration offices, but now they are being monitored and evaluated by provincial administration. The target of achieving the electrical usage of 1500 kWh per capita annually by the year 2030 is enlisted in the Nepal's SDG Roadmap (NPC, 2017).

From the White paper published by MOEWRI in 2018, it is planned to escalate the per capita electricity demand to 700 kilowatt hour in 5 years and 1500 kilowatt hour in 10 years. For this, the energy resources that has been used in households, institutions, transportation and industries should be transformed with electricity. The energy efficiency will be increased and the renewable energy projects will be connected to the national electricity grid. The inefficient technologies will be replaced with efficient electrical technologies and the waste to energy concept will be used to utilize the energy from the household and industrial wastes. Nepal will be independent in electricity in upcoming three years with the development of newer and larger hydropower plants. The decade from 2018 to 2028 will be the energy decade for Nepal. The concept of 'One province, One mega project' plans the production of 2,358 MW from larger hydropower projects Sunkoshi-2, Sunkoshi-3, Tamakoshi-5, Khimti Sivalaya and Kokhajor in Bagmati Province. The concept of 'One home, One energy house' plans to promote the roof top solar in each home connected to the national grid based on net metering and net payment. The concept of 'One house, One Electric Stove' promotes the use of electric stove in every households reducing the use of LPG gas minimizing the import costs (MOEWRI, 2018).

2.6. Challenges on Integration of Renewable Eenergy in Nepal

The chief challenges for the installation and production of RETs in Nepal are as follows.

Policy and regulatory barriers

The government has made the subsidy policy for renewable energy, but still its implementation is too low because of several legal procedure and acts. For the present political situation, the energy sector is centralized and lacks the transparency which causes lengthy processes for the implementation (RERL, 2018). The three levels of government have to assure the proper coordination in order to install a desired renewable energy plant in any area of the country. Because of this non-transparency, the subsidies have a risk of misappropriation (Karki et al., 2010). The distribution of powers of the three levels of government are enlisted in Schedule 5 to 9 as per the Article 57 of Constitution of Nepal, 2015.

Institutional barriers

Before the establishment of the federal system in Nepal, the only governmental agency involved in the promotion of RET in Nepal was AEPC. Therefore, there was a very poor energy planning in the local cities (RERL, 2013). But after the Constitution of Nepal gave the permission and authority of promoting Alternative energy to the state level and local level government, such government are also planning to make them independent in context of energy.

Financial and technical barriers

The development of RET in Nepal is mostly funded by foreign donors. The installation cost of the RET is very high compared to the traditional fuels for remote areas (RERL, 2018). Since the rural villages in Nepal have low economic condition, it is observed unprofitable to extend the electricity to very remote areas (AEPC, 2017).

2.7. Global Energy Use

The energy use in the world is rapidly increasing, which has caused the problems on difficulty of supply, energy source exhaustion and severe environmental impacts. During 1984 to 2004, the consumption of energy has raised by 49%, and the emission of CO_2 has also raised by 43% with the average yearly growth of 2.0% and 1.8% respectively (Lombard, 2008). The developed countries' use of energy will grow at the yearly rate of 1.1% and emerging economy countries with 3.2%. China is expected to double its energy consumption is only 20 years with annual growth of 3.7% (Lombard, 2008).

Since 2000, the consumption of worldwide energy has been increased with about three times in 2018. The demand has grown by 2.9% in the year of 2018. From business as usual scenario, the global energy consumption is predicted to reach 740 million terajoules in 2030 which is 30% growth than now and 77% growth from 2000. Today, 83% of the total energy is available from the fossil fuels which emit the high amount of carbon dioxide in the atmosphere. The global CO_2 emission from the energy usage has reached 33 Giga tonnes in 2018. The global electricity demand has reached more than 23,000 TWh in the year 2018 (IEA, 2019).

2.8. Consumption of Energy in Buildings

The final consumption of energy in a specific area can be broken down to the three major sectors, namely: industrial, transportation and others. The 'other' includes agricultural, household and service sector. For the developed countries, the building energy consumption account for 20 to 40% of final consumption and considered as the third main sector (Karekezi et al., 2012). For Nepal, the household energy sector is the highest energy consumption sector (NEA, 2019).

2.9. Clean Energy for Household Cooking

The use of improved cook stoves reduces the average kitchen PM 2.5 from 40 to 50% which is above the guidelines of World Health Organization. This can be only achieved by the replacement of currently available cooking stoves with cleaner fuels such as biogas, LPG and electricity. The WHO guidelines describe the essence of cleaner fuels like LPG, biogas and natural gas and other modern least polluting fuels (Quinn, 2018).

2.10. Energy Requirements of a Developed World

For the economic, social and cultural development in complex societies, a proper and suitable supply of energy is necessary. The general assembly of UN in 1986 adopted "Declaration on the Right of Development" (UN, 1986) which set a catalogue for equality of opportunity for basic needs like food, housing, health, education and employment. Energy is required in different forms for providing all these facilities which are linked to human development. So, energy plays a vital role to overcome poverty (Cao et al. 2016). Different studies are carried out to investigate the relation between the degree of country's development with the usage of energy.

2.11. Smart Sustainable Cities (Bibri 2017)

The idea of smart and sustainable cities has taken attention to the technologically and ecologically advanced countries. Bibri reviewed the existing model of sustainable development of cities and the approaches for the smart cities. The approaches are then evaluated as well as compared in idea of sustainability. An integrated approach is derived from theoretical perspectives. This model addresses the uncertainties and limitations of the existing models for sustainable cities with the integration of Information and Communication Technology for computing applications (Bibri, 2017)

2.12. Effect of Use of Renewable Energy on Economic Growth

Ernst & Young Global Limited developed the long-run dynamics of the GDP for the 38 countries from 1991 to 2012. This analysis shows the cross sectional interrelation between different countries. The 38 countries selected were divided into three categories. In the first category, the 23 countries like China, Austria, Spain were assigned showed significant economic growth with the integration of Renewable energy. They showed the prominent shifting towards the renewable from non-renewable energy sources. It was found that the renewable energy sources showed an adverse economic growth for the 5 countries like United States, India, Israel because of their high ongoing production on thermal and nuclear power plants. And lastly for the remaining 11 countries like Australia, Brazil, Japan, it was observed that the integration of renewable energy did not significantly drive the growth in economy. This was because they have already practices the renewable energy integration from several years with reducing the number of thermal and nuclear power plants. Renewable energy integration has increased significantly in the last 25 years in many countries. The different countries have different effects of Renewable energy integration because of difference in various factors like economy, culture and other relevant factors (Bhattacharya, 2015).

2.13. Energy Demand Reduction

Sorell (2015) has performed the review on issues, challenges and approaches for the minimization of energy consumption in a city. The enhancement of energy efficiency and the reduction of the final energy demand required for the sustainable development path for the cities. Most of the countries are specifying some numerous policies in order to decrease the total energy consumptions. The correlation between consumption of energy and growth of economy is found to be strong so that energy consumption is highly dependent upon economic growth. The effective response to climate change requires the rapid reduction in energy demand which constitutes the large socio-technical transformations. The main challenge to the policy is to provide the direction by delivering the fast change avoiding climate change.

2.14. Energy Planning of Other Municipalities of Nepal

An energy planning study was carried out for the Reshunga Municipality located in Gulmi district of Province 5 with the analysis on energy demand as well as emissions under four scenarios. From the study, it was concluded that the total energy of 214.8 TJ was consumed in the base year among which 78.25% was supplied by biomass from the forest. Cooking and water heating were the highest demanding energy consuming tasks comprising 58% and 26% of the total consumption respectively. By the year 2030, the consumption of energy will meet 245.3 TJ in Business as Usual Scenario. But under Sustainable development scenario, the final energy demand will be decreased by 23.14%. The cost benefit analysis study concluded that the investment of 0.64 Million USD is required for sustainable development of the municipality and it will reduce the GHG emissions by 47.79 kilo tonnes of Carbon dioxide equivalent (Panthi and Bhattarai, 2018).

An energy model was developed for the Palungtar Municipality situated in Gorkha District in Gandaki Province. The implementation plans were made for the Palungtar Municipality using the bottom up approach starting from the level of wards then to the municipality level. The plan included the options for technology use and the mechanisms for the energy delivery for the distinct areas of the Palungtar Municipality. The activities concerned for the implementation in the Palungtar Municipalities were divided in eight distinct sectors which were: Use of Household Lighting / Electrical Appliances, Electricity Grid Upgrade, Household Cooking, Community Lighting and Endues, Project Inventory / Pipeline Development, Small Industry / Service, Revenue Generation, Activities of Capacity Development (RERL, 2018).

CHAPTER THREE: RESEARCH METHODOLOGY

The figure 3.1 shows the methodology for the energy sector analysis that has been implemented for the research. First of all, the literatures related to the thesis are collected from the internet and are reviewed. The detailed study on the energy based studies carried out on the different areas of the country are carried out. The questionnaire is prepared and the household survey of is conducted on the sampled households of Neelakantha Municipality. The data are allocated in the Microsoft Excel software and different calculations are conducted to develop the base year data with the demand. The demand and supply data which are gathered with the secondary reports and the sample survey are then verified with the key informant of the municipality. The energy balance for the base year is then developed which shows the overall energy demand and supply situation of the municipality. They are categorized according to the fuels used and the purpose of their use. Then the resource assessments for the biomass, petroleum and electricity are carried out for the municipality. The two distinct scenarios are developed for the future energy analysis of the household sector of Neelakantha Municipality. The future energy scenario is developed until the year 2050 under the current trend as Business as Usual (BAU) Scenario. On the other hand, further strategic actions are applied for the Sustainable Development (SUS) Scenario ensuring the replacement of inefficient and emissive conventional technologies with the proper efficient technologies in the upcoming years. The demand analysis, emission analysis and economic analysis are then carried out for both scenarios up to the year of 2050 using the Low Emission Analysis Platform (LEAP) computer software. Then the comparison of these scenarios are performed, and the best one is suggested for the implementation. The time to time progress report is submitted to the supervisor and updating continuously with the feedbacks, the final report is prepared.

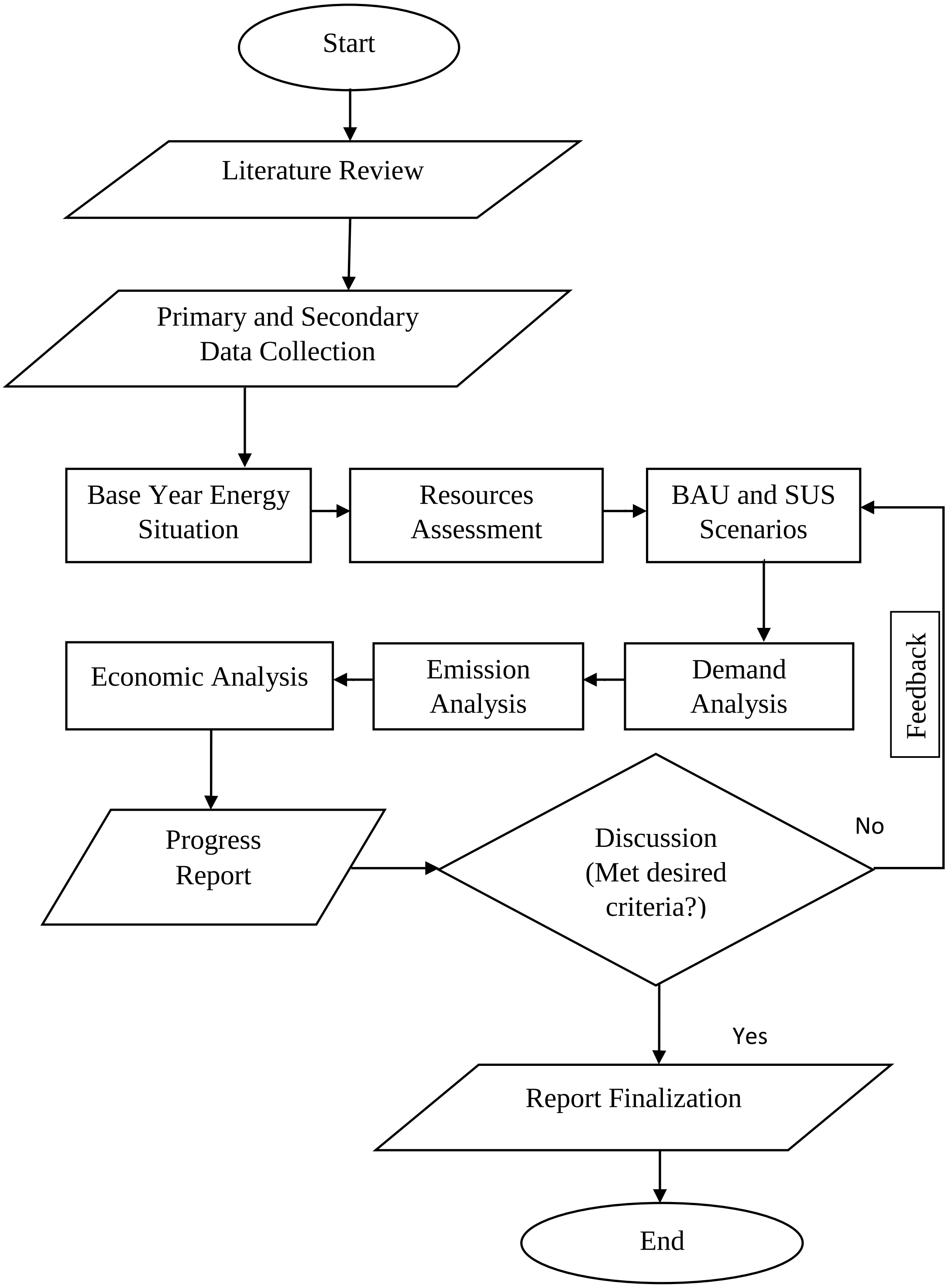

Figure 3.1 - Methodological Flowchart for Energy Planning

3.1. Methods of Data Collection and Analysis

3.1.1 Sampling

The sample size for the collection of survey data in the Municipality households is calculated using the formula provided by Krejcie and Morgan (1970) stated in equation 1. Since the households of the municipality contain large study population of 71,131, clusters of each wards are distributed based upon the population on each ward after that random sampling is carried out inside each cluster. The distribution of households within municipality is as shown in Table 3.1 and cluster sampling is applied inside the ward so as to decrease the bias. The low income groups and high income groups are associated together in the sampling.

Table 3.1 Sample size for household data collection

Ward No.	Population	No. of Households	Sample size taken
1	2,589	572	4
2	5,148	1,163	9
3	12,004	3,370	20
4	3,392	813	6
5	4,588	994	8
6	3,053	687	5
7	3,207	752	5
8	3,574	793	6
9	3,679	880	6
10	3,931	696	7
11	4,067	957	7
12	2,808	632	5
13	2,713	612	5
14	4,762	1,063	8
Total	**71,131**	**14,524**	**101**

The sample size is calculated using the equation 1 where the confidence interval is taken as 95%, population proportion as 7% and degree of accuracy as 5%. The total number of sample households is then calculated and found to be 101.

$$S = \frac{\lambda^2 NP(1-P)}{\delta^2 (N-1) + \lambda^2 P(1-P)}$$ ……………………….….Equation 3.1 (Krejcie and Morgan, 1970)

The primary data are collected with the sample survey with the visit on the respective site on each ward of Neelakantha Municipality. Also some of the useful data are collected through the secondary sources of different publications and organizations. While going for the site visit, various group discussions are conducted in the municipality office directly with Mayor Bhim Pd. Dhungana and other officials of the municipality. The information regarding the supply and demand of the electricity inside the boundary of Neelakantha Municipality is collected from Nepal Electricity Authority (NEA), Dhadingbesi. 101 households are then chosen and surveyed for the necessary data collection for household sector to prepare the base year household energy scenario. Also the information on the supply of petroleum are collected from authorized dealer of Nepal Oil Corporation available in the municipality.

3.1.2. Literature Review

The review of the related secondary articles is carried out which consisted of the published and unpublished reports from different institutions, books and journals. Also the recent trend and policies for the different developed and developing countries are studied. The energy situation and policies of Nepal’s sustainable development are studied.

3.1.3. Data Collection Components

Energy Demand Assessment

For the assessment of energy demand, the sample survey is carried out with clustered random sampling in each ward of the municipality. The questionnaire was used to ask the question to the informants. The energy data are converted on the basis of yearly consumption. Each energy units are converted in terms of Giga Joule and Tera Joule. The population and economy are taken as the driving variables for energy demand of the municipality. The different fuels used in the households of Municipality are categorized to conventional, commercial and renewable energy sources.

Technology Assessment

The currently used technologies for different purpose in the household sector are then accessed. The efficiency and emission for each technology are then noted. The data for penetration of each technology in the households of Neelakantha is then collected. The current cost for the technology and subsidy policy are then collected and analyzed. The technology assessment is generally based on secondary data.

Resources Assessment

For the assessment of resources, the supply potential data are collected from secondary reports as well as from primary survey data. The supply resources consist of traditional energy like fuelwood, agricultural residue and other biomass; commercial energy such as electricity and petroleum products and modern alternative energy sources such as wind, solar and micro-hydro. The resource assessment is also secondary data based.

3.1.4. Questionnaire for Survey

The questionnaire is prepared in research consists of numbers of questions which is designed to support the direct observation. The questionnaire is prepared for collecting the primary data for the baseline energy consumption in households. Each sample household is taken as part of questionnaire survey. It also helps to get a standardized response from the respondents.

The questionnaire is developed in both English medium as well as Nepali medium for easing the communication of the asker with the respondents of the survey. The questions are listed down which are enough to evaluate the present energy situation of the Municipality. Also the future willingness to introduce the newer energy technologies are added in the part of the questionnaire. The questionnaire is divided into three sections with general family information, energy use information and technology use information. The answers to the questionnaires are filled up in each households of survey. The questionnaire used for the survey in this research is summarized in Appendix IV of this report.

Section 1: General Information of Respondents

It includes the name, contact, age, sex, ethnicity, family information and economic background of the respondent.

Section 2: Information on Energy Use

It includes the consumption of lighting apparatus used in each household, other electrical appliances, the consumption on cooking, space heating, water heating, cooking animal meal, the consumption of Firewood, LPG, Animal wastes etc.

Section 3: Information on Energy Technologies

It includes the residential information about the use of technology in cook stoves, biogas technology, solar home system, mini/micro/pico hydropower, solar/wind microgrid, National electricity grid.

3.2. Energy Analysis

3.2.1 Energy Planning and Scenario development

The process of energy planning comprises preparing the strategic action plans to improve the current energy performance to attain sustainable development with regards to energy consumption and production. A scenario is developed for Sustainable development and another for the Business as Usual.

Final Energy Scenario

The scenario analysis for the changes in final energy demand, fuel mix, per capita energy consumption, consumption of electricity is calculated and analyzed. These results help to measure the energy-specific targets set up by various plans and policies. This scenario also provides information on Renewable Energy Technologies and the penetration ratio.

Emission Scenario

The emission scenario presents the environmental impacts in terms of emissions of greenhouse gases as well as emissions such as black carbon, particulate matters and others. These gases have detrimental effects on human health, crop production, as well as climate.

Economic analysis

For justifying the feasibility of the proposed action, it is necessary to perform the economic analysis with the cost benefit analysis between two scenarios.

3.2.2 Methodological Framework

Methodological Framework for Energy Planning and Scenario Analysis applied for this study is based on the bottom-up approach, i.e. all possible energy activities are considered at the root level. The initial data collected from the survey is used to develop a base year energy overview where the base year is taken as 2018. Then the energy scenarios are developed for up to 2050. Then the demand analysis, supply analysis, environmental analysis and economic analysis are performed step by step considering the different purposes and fuels in the households.

3.2.3 Energy Demand Projections

For forecasting the energy demand in the municipality in the upcoming years from 2020 to 2050 from the data of energy situation in the base year, the driving variables of Population of the municipality and GDP per capita of the municipality are taken so as to compute the final energy service demand per capita. The relationship equation for the regression between Energy Demand per capita, Population and GDP per capita for distinct household purposes are achieved using the equation 3.2 (Shakya and Shrestha, 2011).

$$ESD_{i,t} = (\frac{POP_t}{POP_0})^{\alpha i} \times (\frac{GDP_t}{GDP_0})^{\beta i} \times ESD_{i,0} \quad \text{……………………………..………...……Equation 3.2}$$

Where,

$ESD_{i,t}$ and $ESD_{i,0}$ = Per capita Energy Service Demand for purpose 'i' in t'th year and base year

POP_t and POP_0 = Municipality Population in t'th year and base year

$GDP_{i,t}$ and $GDP_{i,0}$ = Per capita GDP for purpose 'i' in t'th year and base year

αi and βi = Population Elasticity and GDP elasticity

3.2.4 Elasticity Calculations

The national energy consumption for different purposes from the previous years are listed from previous 20 years. Then the Energy service demand per capita for each year is calculated. The population and GDP per capita of the country are also listed down and the regression analysis is performed on the equation 2 to calculate the GDP elasticity and Population elasticity which is to be used to carry out the future projection of the energy service demand.

3.2.5 Assumptions for the Scenario Development

Business as Usual Scenario (BAU)

BAU scenario assumes that the trend which is going on from previous 10 years is permitted to continue in the similar way for the future years too with no technology intervention in upcoming years. In this scenario, the growth of GDP is assumed as the past 10 years' average annual growth of GDP in Nepal whose value is 4.60%. The population growth of the past 10 years of Neelakantha Municipality is calculated to be 1.43% and assumed to increase with the same rate for further years upto 2050. The technologies for end uses of households are not altered in this scenario. Table 3.2 shows the GDP and Population of Nepal in past 10 years. Other necessary assumptions taken for the study are noted in Appendix III.

Table 3.2 GDP and Population of Nepal in past 10 years (Source: World Bank Group)

Year	Population (in Million)	GDP per capita (in 2018 NRs.)
2008	26.4759	52,122.40
2009	26.7411	52,879.20
2010	27.0231	65,139.80
2011	27.3271	76,133.20
2012	27.6499	74,996.90
2013	27.9853	75,748.20
2014	28.3232	77,686.40
2015	28.6563	82,187.60
2016	28.9828	80,203.20
2017	29.305	91,858.80
2018	29.988	104,060.00

Sustainable Development Scenario (SUS)

The Sustainable development strategies developed by ministry of urban development of Nepal are followed in this scenario with the intention to achieve all the targets of sustainable development. In this scenario, different interventions are carried out. The population growth is taken as the average of the past 10 years which is 1.43%, but the annual growth of GDP is taken to be 7% based upon the sustainable development strategy of Nepal. (MOUD, 2017). The assumptions taken for the annual raise of population and yearly growth of GDP for the two scenarios are shown in Table 3.3.

Table 3.3 Assumptions for annual population and GDP growth

Growth rate	Population	GDP
BAU scenario	1.43%	4.60%
SUS scenario	1.43%	7.00%

The action plan of the sustainable development of urban areas for household targets to substitute all the traditional technologies of cooking into electric cooking technology by 2030 with the use of clean electric cook stoves. The fluorescent tube lights, CFLs and incandescent bulbs are to be substituted with highly efficient LED bulbs and 30% of the total lighting are to be done from the Solar Home System installed in the rooftop of households by 2030. Also the households in the city area which are serving different governmental and non-governmental offices in rent have to install large sized SHS extending the capacity from 500 to 1,500 kW that can also run the electrical appliances of small wattages. In this scenario, the year 2030 is taken as the major fuel switching year confirming the transformation of the non-efficient energy technologies to the efficient means of technology mainly with electricity.

3.2.6 Tools used for the Analysis

For the computation of energy demands and analysis in this study, data collected in questionnaire are filled and manipulated in excel base. Low Emission Analysis Platform (LEAP) software is used for the development of different scenarios, their analysis and projection of the energy demand from 2020 to 2050.

Low Emission Analysis Platform (LEAP)

The LEAP is a computer software developed by the Stockholm Environment Institute (SEI) that is generally used for energy policy analysis as well as climate change mitigation assessment. This software has been used by various countries for analysis of energy system ranging from local level to national level for planning of integrated resource, mitigation assessments for greenhouse gas (GHG) and Low Emission Development Strategies including study reports acquiesced to the U.N. Framework Convention on Climate Change (UNFCCC) such as Intended Nationally Determined Contributions on Climate Change (INDCs) - a part of Paris Agreement. It has gained popularity in developing countries due to its simplicity, flexibility and low data requirement. The integration of cost-benefit analysis makes it more suitable for financial planning as well. It had changed its name from Long-range Energy Alternative Planning Software to Low Emission Analysis Platform in 2020 (Heaps, C.G., 2020).

The LEAP software follows the approach of end use and consumer demand inside a study area. By dividing the energy usage in the society into sectors, subsectors, end-uses and devices, the LEAP software can be used to analyze the current energy status in the study area. LEAP can also analyze the emissions in the respective study area due to the use of energy resources. LEAP can also generate the energy balance showing the production, transformation and supply of the different energy resources to satisfy the consumer demands. With the development of the scenario for the interventions in the use of energy technologies, the future energy planning can also be carried out using LEAP. The LEAP model can also generate the comparative summary of the costs as well as benefits for the different scenarios. The charts and tables in the LEAP model help to analyze the energy usage, emissions and costs in an easier way (Heaps, C.G., 2020).

A municipality is a local level administrative boundary of the country. Since the local level is given the right of governing the area, it is essential to plan for the sustainable development of the local level urban and rural municipalities. The baseline energy situation of the municipality can be analyzed with the survey. For the energy planning of the municipality, LEAP is the best software model which can be used to carry out the future planning under different scenarios.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Energy Mix for Households

The data in the Table 4.1 shows the overall energy mix of the energy according to the type of fuel and the purpose the energy is used for in the residential sector of Neelakantha Municipality. It shows the share taken by different sources of energy for the various purposes in the base year for the households of Neelakantha Municipality in GJ. Also the per household and per capita consumptions of energy are calculated by dividing the total consumption with the numbers of households and total population respectively. From the calculation, it is noticed that the use of firewood which has the share of 44.3% of total energy consumption is still dominant in the Municipality. LPG and electricity follows the energy consumption after Firewood with the share of 34.3% and 19.6% of electricity respectively. The major consumption of energy resources in the household sector is observed for cooking purpose which is 67.3% of the final consumption of energy in the base year 2018. The per capita total energy usage for the household sector of the Municipality is calculated to be 4.11 GJ per capita per year in the base year. This figure is far lesser than the national average energy usage of Nepal which is 14.2 GJ per capita annually which is because of the rural livelihood in the municipality. The average per capita electricity consumption in the households of Neelakantha Municipality is calculated to be 224 kWh per capita per year which is slightly above the national average of 220 kWh per capita per year.

4.2. Energy Balance for the Base Year 2018

The energy balance sheet of the residential sector of Neelakantha Municipality is prepared with the information on the energy supply, demand and transformation. The energy requirements of the Neelakantha Municipality are expected to be fulfilled through the indigenous productions and the imports. An amount of energy produced by the hydroelectricity is exported out of the boundary of the Municipality. As the biomass are extracted from local forest and the agricultural activities, they are the indigenous energy resources of the municipality. Since there is very small power generation through the hydropower plants, the total electricity demand of the municipality is supplied through the national grid of Nepal Electricity Authority.

Table 4.1 Energy Share in base year 2018 (GJ)

	Cooking	**Water Heating**	**Water Pumping**	**Lighting**	**Space Cooling**	**Space Heating**	**Electrical Appliances**	**Others**	**Total GJ**	**Share**
Firewood (GJ)	78,797	15,759	-	-	-	6,859	-	28,198	129,613	44.3%
LPG (GJ)	77,055	19,264	-	-	-	4,086	-	-	100,405	34.3%
Biogas (GJ)	5,284	-	-	-	-	-	-	-	5,284	1.8%
Electricity (GJ)	35,804	10,741	522	6,655	672	-	2,987	-	57,381	19.6%
Total GJ	**196,940**	**45,764**	**522**	**6,655**	**672**	**10,945**	**2,987**	**28,198**	**292,684**	
Share	67.3%	15.6%	0.2%	2.3%	0.2%	3.7%	1.0%	9.6%	67.3%	
GJ per year per capita	2.77	0.64	0.01	0.09	0.01	0.15	0.04	0.40	4.11	
GJ per year per HH	13.56	3.15	0.04	0.46	0.05	0.75	0.21	1.94	20.15	

The energy on the demand side as well as on the supply side in the Neelakantha Municipality are analyzed for the base year 2018. Production of energy inside the municipal boundary, imports and exports for the different type of fuels are categorized. The energy balance table is prepared for the year 2018 which is shown in the Table 4.2. The total energy demand of 292.35 TJ is supplied through the electricity, LPG, firewood, charcoal, biogas and solar photovoltaics in the municipality. The electricity of 14.47 GJ is transmitted to neighbouring local levels from this municipality.

Table 4.2 Energy Balance in base year 2018 (TJ)

	Electricity	**LPG**	**Wood**	**Biogas**	**Solar**	**Off grid**	**Total**
Production	-	-	127.04	5.32	2.50	-	134.86
Imports	77.86	96.21	-	-	-	-	174.47
Exports	-	-	-	-	-	-2.50	-2.50
Total Primary Supply	77.86	96.21	127.04	5.32	2.50	-2.50	306.83
Off grid electricity	-	-	-	-	-2.50	2.50	-
Grid electricity	-	-	-	-	-	-	-
Transmission and Distribution	-14.47	-	-	-	-	-	-14.47
Total Transformation	-14.47	-	-	-	-2.50	2.50	-14.47
Residential sector	63.39	96.21	127.04	5.32	-	-	292.35
Total Demand (TJ)	**63.39**	**96.21**	**127.04**	**5.32**	**-**	**-**	**292.35**

4.3. Energy Technologies

The technologies for the energy usage in the household sector are shifting to modern efficient fuels from the traditional less efficient fuels like solid biomass and LPGs. From the calculation for the base year, it is found that around 40.01% of the total energy consumed in cooking is extracted from firewood and 39.13% are consumed with LPG gas. The cooking technologies are classified as Traditional Cookstove, Biogas, Mud ICS, Kerosene Stove, Rocket Stove, Metallic ICS, Briquette Stove, LPG gas and Electrical Stove. Some of the households have already started using the electric cooker for the cooking purpose which consume 18% of the total cooking consumption. Since some of the households in the municipality are using biogas for the cooking purpose, 3% of cooking energy is supplied through biomass. Energy technologies used in cooking are shown in figure 4.1. LPG and Firewood are seen as the most used energy source for cooking in the municipality.

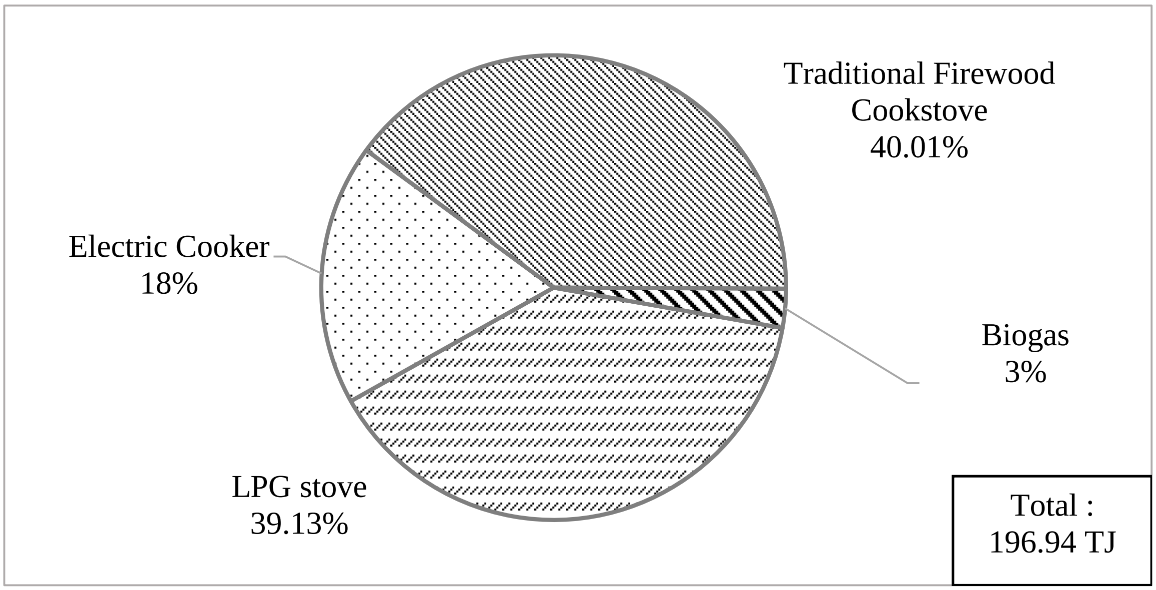

Figure 4.1 Energy Technologies in Cooking in 2018

The major household electrical appliances which consumes the most of the electrical power are Rice cooker, Television, Refrigerator, Computer, Iron and Mobile Phones. Almost all the households in the Municipality are supplied with the national electricity grid but due to the weather problems, the electricity service is not reliable all the time in the rural areas of the municipality. From the survey, it is found that 33% of the total residents have placed the electric meter of 15 amperes and the rest have placed that of 5 amperes. The sixty percent of the urban area of the municipality and thirty percent of the rural area of the municipality use electric fan as the technology for space cooling. The majority of the rural livelihood of the municipality only use electricity for the lighting purpose. For the animal feeding purpose, majority of the households are using firewood from the nearest forest.

Figure 4.2 displays the energy distribution chart of lighting technology in the households of Neelakantha Municipality. Fluorescent tube light is the most used lighting technology comprising 45% of the total lighting energy in the households of Neelakantha Municipality. The use of incandescent lamps is still seen in the rural areas because of its lower purchase cost.

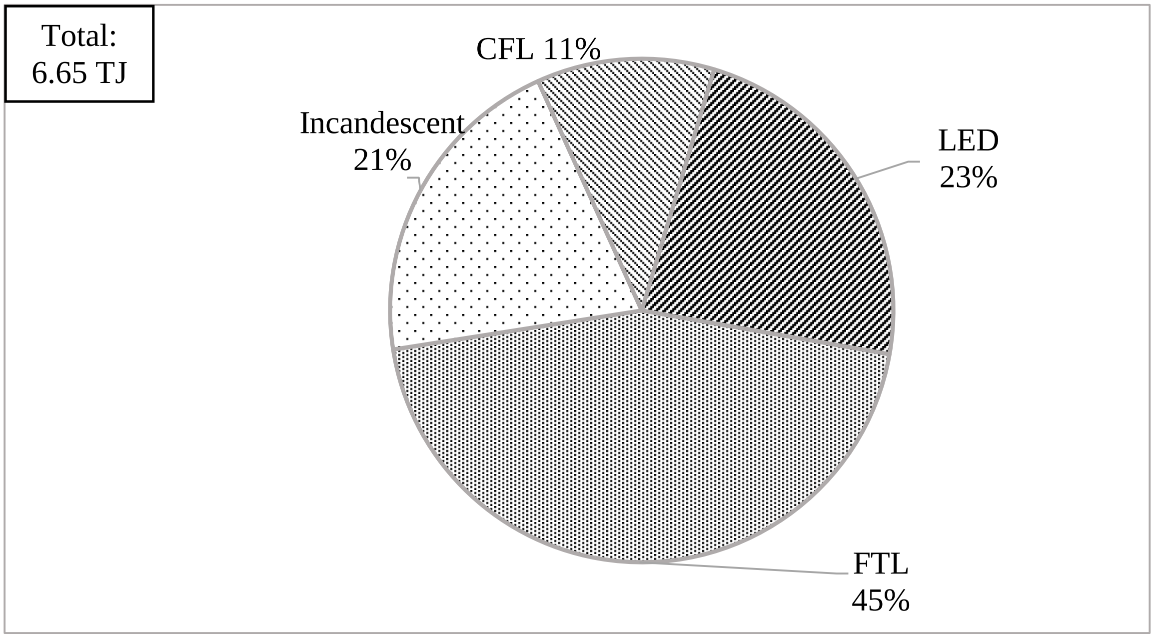

Figure 4.2 Use of lighting technology in 2018

For the purpose of animal feeding, all the farmers are found to use the biomass like firewood as the energy source. From the survey, it is found that there is not such a significant use of modern energy technologies like Solar Home system and Biogas Technology. It is found that almost all households are provided through grid electricity.

4.4. Energy Resources Assessment

4.4.1. Biomass

The major biomass energy sources used in Neelakantha Municipality are firewood, animal wastes and agricultural residues. Around 49.73% of the whole Municipality area is covered by forest, and around 47% of the land is utilized for agriculture (CBS, 2011). Although there is a huge potential for the biomass resources, it is essential to control the deforestation for the sustainable development goals.

4.4.2. Solar and Wind

The annual solar radiation for Neelakantha Municipality is found to 4.704 $kWh/m^2/day$ with the annual average sunshine days of 300 days. The average wind density is found very low with the magnitude of only 28 $W/m^{2,}$ which shows that wind power generation is not a better option for the municipality (AEPC, 2017).

4.4.3. Municipal Waste

After the calculation from the survey, it is found that the average per capita waste of 49.37 kg is generated each year. Only 33% of the total population is found to reach the waste collection conducted by the municipality. About 30% of the population are found to use them as organic fertilizer, and the remaining are disposed of in the open area. The fertilizer thus prepared are used for the production of agricultural products. There is a very few utilization of waste to energy conversion using biogas.

4.5. Population Elasticity and GDP Elasticity

The national energy consumption for different purposes from the previous years are listed from 2001 to 2018 referring to the Trading Economics. Then, the population and per capita GDP of the country are also listed down for each year referring to the World Bank data. The regression on the equation 2 is carried out where the population and per capita GDP are chosen as the driving variables. The logarithm of equation 2 is taken to convert the regression equation into linear regression equation.

$ESD_{i,t} = (\frac{POP_t}{POP_0})^{\alpha i} \times (\frac{GDP_t}{GDP_0})^{\beta i} \times ESD_{i,0}$ ……………..…Equation 2 (Shakya and Shrestha, 2011)

After conducting the regression analysis, the elasticities for Population and per capita GDP in the final energy intensity for the different household purposes are calculated. The confidence interval of 95% is assumed and the regression analysis is carried out through the statistics tool of Microsoft Excel. Table 4.3 shows the calculated GDP elasticity and Population elasticity for the different purposes. The p-value for the GDP elasticity for cooking, water heating and space heating purposes are found to be 0.8219 which is very much greater than 0.05 and that for population is 0.0046. This signifies that the value of per capita energy demand is very less sensitive with the value of GDP per capita in comparison to the population of the municipality. But for the other purposes such as Water Pumping, Lighting, Space cooling and Electrical appliances, the p-values for both GDP and population are below 0.05 which signifies that the energy demand per capita is sensitive to both the GDP per capita and Population for these purposes.

These elasticities represent the effect of the increase in GDP and population to the per capita energy consumption in the municipality. These elasticities are used to carry out the forecasting of the energy consumption for the future years up to 2050 for the business as usual and sustainable development scenario in the municipality.

Table 4.3 Elasticity calculations

Sub sectors	GDP Elasticity	P-value for GDP (95% confidence interval)	Population Elasticity	P-value for Population (95% confidence interval)
Cooking	0.031621	0.821936	3.338359	0.004591
Water Heating	0.031621	0.821936	3.338359	0.004591
Water Pumping	0.279619	0.006785	2.091975	0.00561
Lighting	0.279619	0.006785	2.091975	0.00561
Space Cooling	0.279619	0.006785	2.091975	0.00561
Space Heating	0.031621	0.821936	3.338359	0.004591
Electrical Appliances	0.279619	0.006785	2.091975	0.00561
Others	0.279619	0.006785	2.091975	0.00561

4.6. Business as Usual Scenario

The value of the final energy demand of the Neelakantha Municipality is expected to keep increasing in future years from 2020 to 2050, just like the past trend with the annual population growth of 1.43% and annual growth of GDP of 4.60% for this scenario. The final energy demand is observed to meet 438 TJ in the year 2030 and 958 TJ in the year 2050 in BAU scenario. In terms of per capita energy consumption, it will increase to 6.16 GJ per capita per year in 2030 and 13.48 GJ per capita per year in 2050. The energy demand for different household energy purposes are represented graphically in figure 4.3. This shows that the share of energy for cooking purpose will be 3.45 GJ per capita per year in 2030 and 5 GJ per capita per year in 2050.

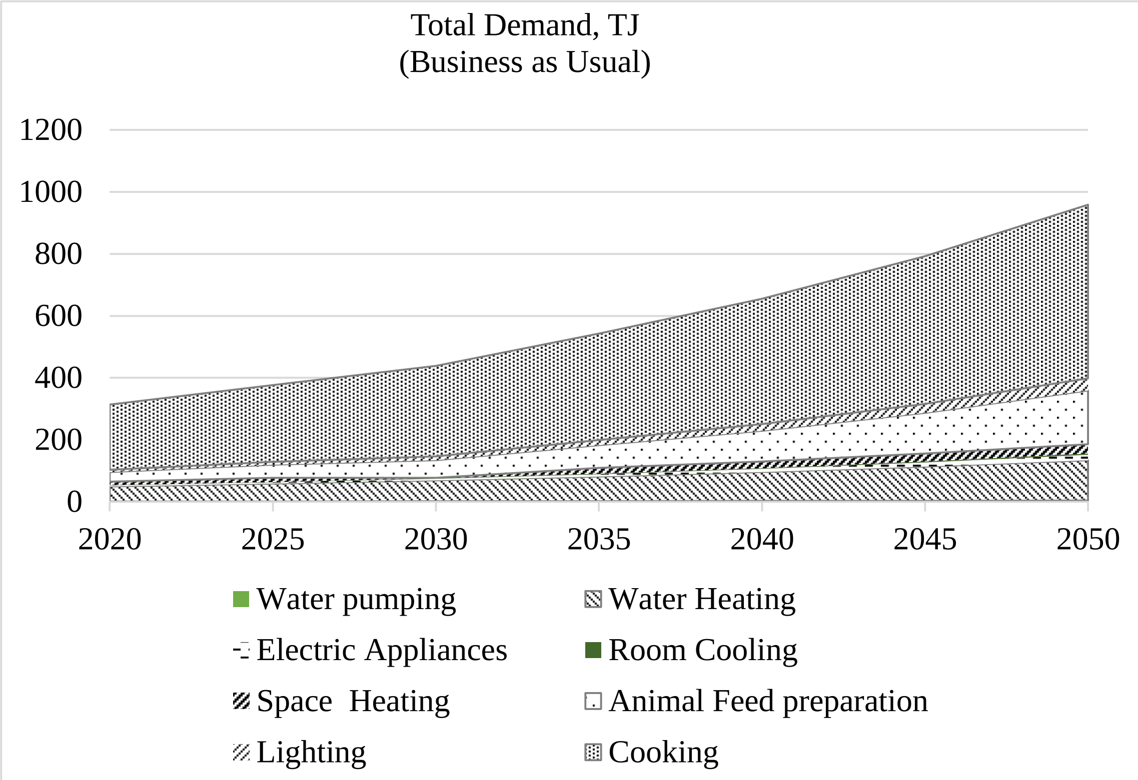

Figure 4.3 Demand for different household energy purposes – BAU

Figure 4.4 indicates the total energy demand from year 2020 to year 2050 for different fuels in the municipality. The demand of LPG will be 1.69 GJ/capita in 2030 and 2.443 GJ/capita in 2050. Similarly, the demand of firewood will increase to 2.35 GJ/capita in 2030 and 4.045 GJ/capita in 2050. The firewood and LPG are still seen dominant in the year 2050 in this scenario limiting the use of electricity to 215.14 TJ which is 1.92 GJ/capita.

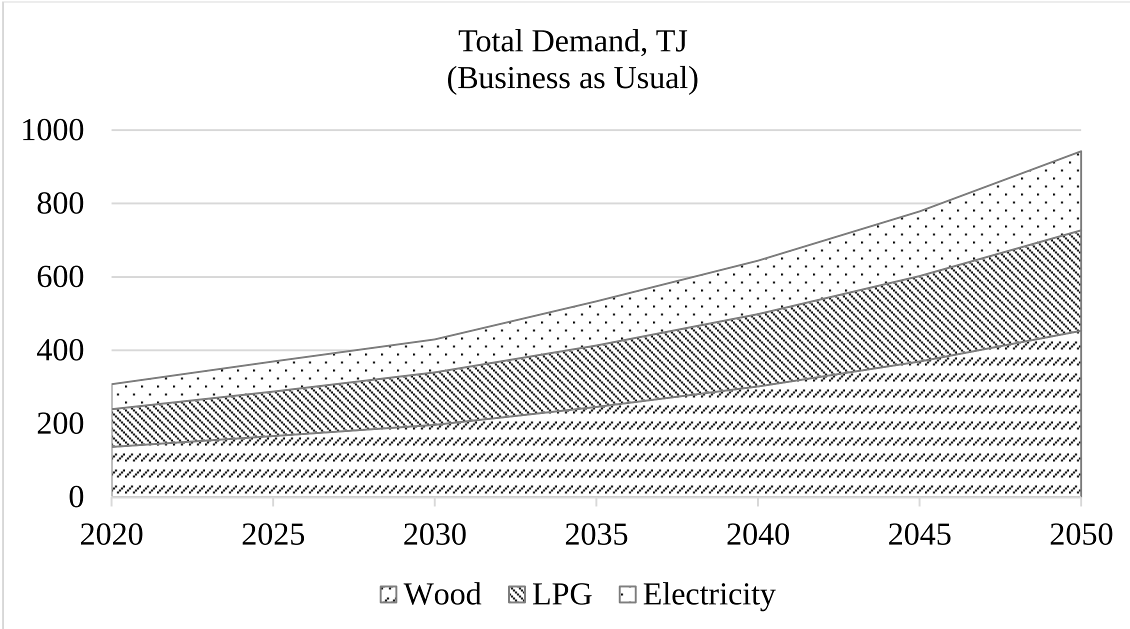

Figure 4.4 Demand for major fuels – BAU

The demand for the different fuels for purpose of cooking is as shown in figure 4.5. It is observed that the use of firewood will be dominant over the study period with the LPG and electricity will follow the consumption after firewood. In year 2030, around 1.30 GJ/capita energy will be consumed with the use of firewood and in 2050, it is seen to be increased to 1.96 GJ/capita.

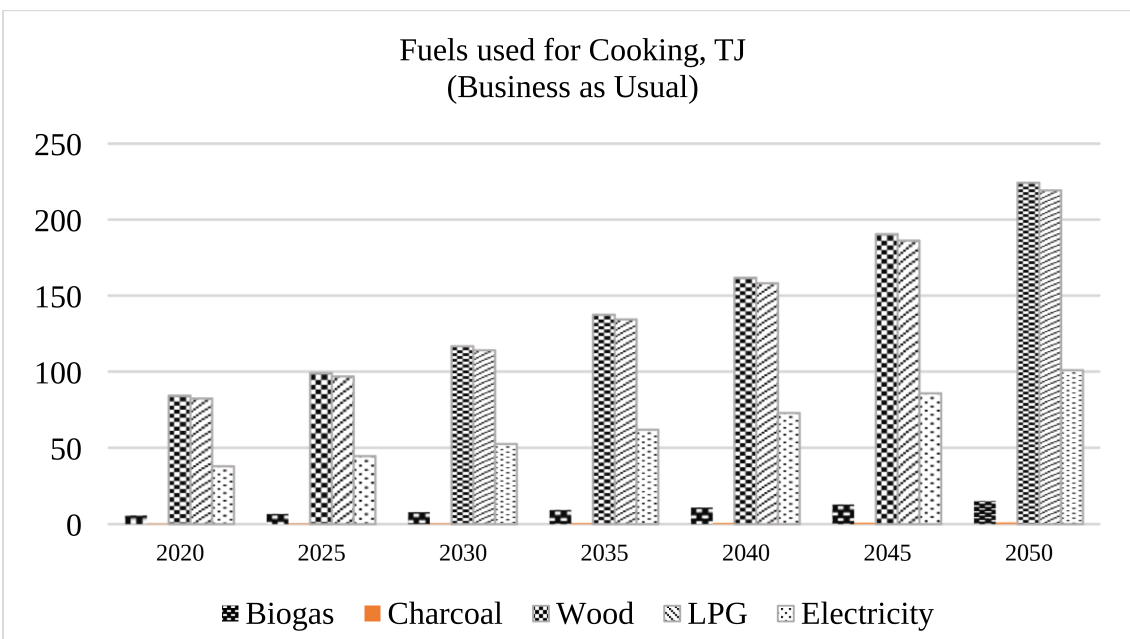

Figure 4.5 Fuels used for cooking purpose – BAU

Figure 4.6 shows the distribution of energy for the household lighting purpose in Neelakantha municipality from 2020 to 2050 for business as usual scenario. The use of CFL for lighting will be dominant throughout the study period with less use of efficient LED efficient bulbs.

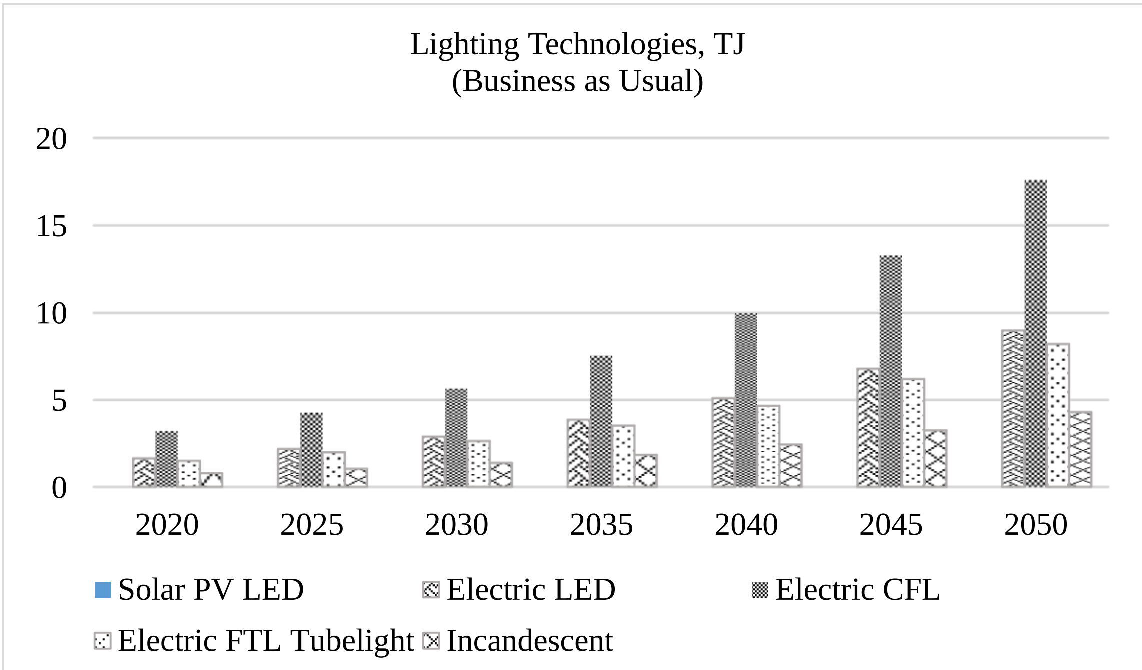

Figure 4.6 Lighting technologies – BAU

As in figure 4.7, it is noticed that there will be negligible usage of electricity for the purpose of feeding the domestic animals and if this trend is allowed to go as usual, there will be no electrification in the technology for animal feeding purposes. The consumption of firewood will reach 0.66 GJ/capita in 2030 and 1.54 GJ/capita in 2050. The major animals that are found in the households are cows, buffaloes and goats.

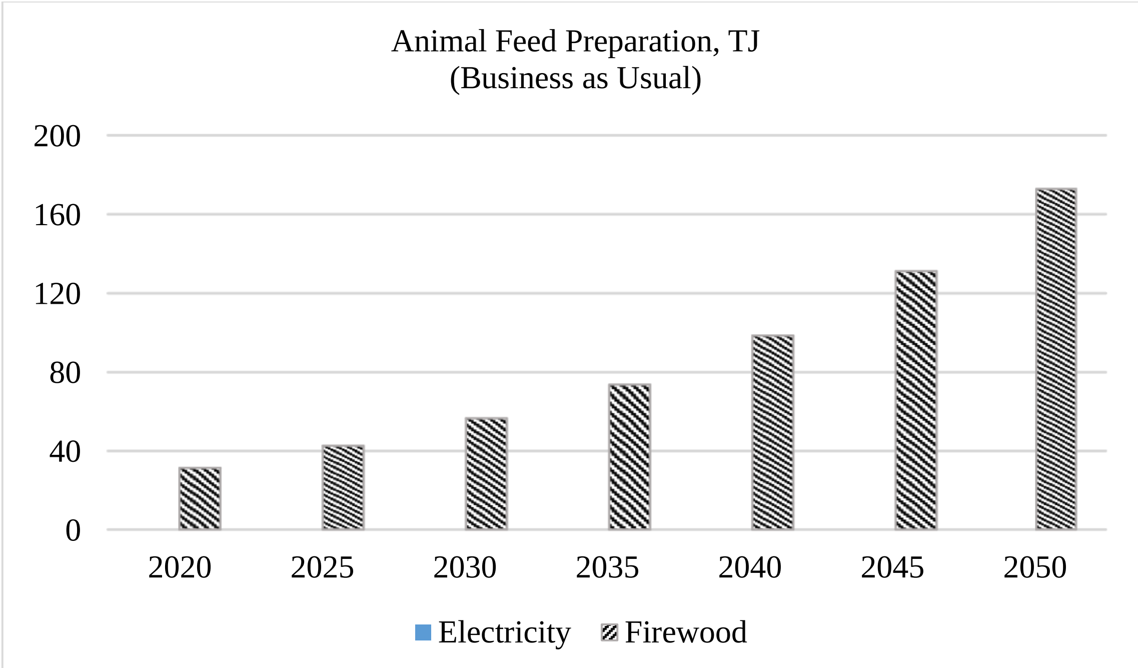

Figure 4.7 Fuels in Animal feeding – BAU

Figure 4.8 shows the use of firewood and electrical power for the purpose of space heating. Some of the households use electrical air conditioner for the purpose of space heating. It is found that the use of firewood in the year 2030 will be 0.085 GJ/capita and that in 2050 will be 0.105 GJ/capita. Similarly, the use of electricity for space heating will increase to 0.117 GJ/capita in 2030 and 0.166 GJ/capita in 2050 respectively.

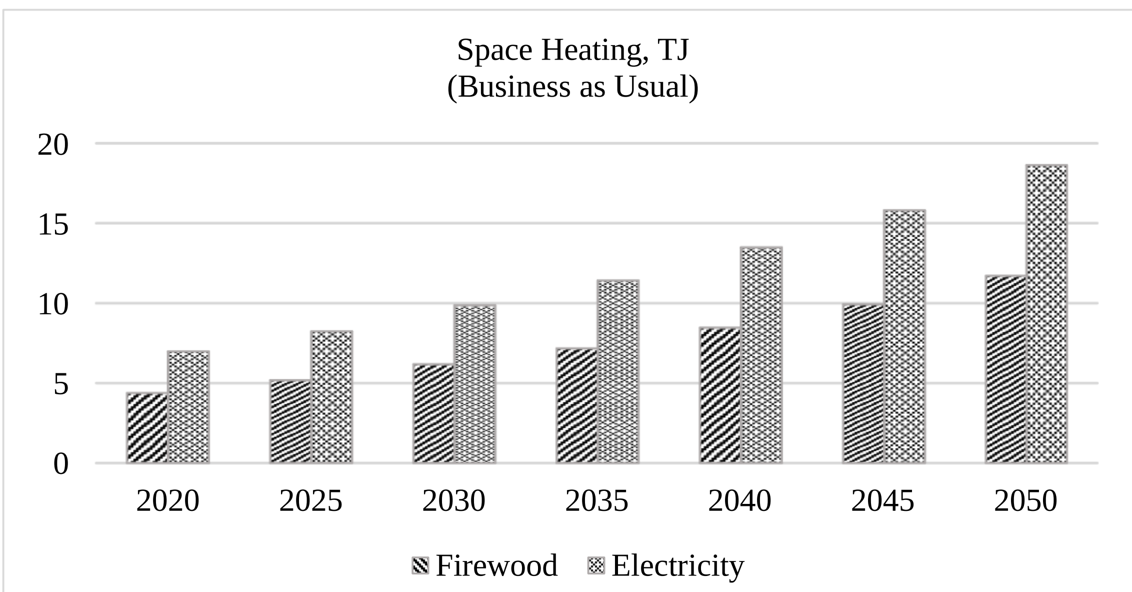

Figure 4.8 Fuels in Space heating – BAU

Figure 4.9 shows the use of different energy sources for the purpose of water heating. The fuels used for water heating purpose are mainly biomass, LPG and electricity. In 2030, the consumption of biomass and LPG for the water heating purpose will be 0.26 GJ/capita and 0.243 GJ/capita respectively. In year 2050, these value increase to 0.47 GJ/capita and 0.43 GJ/capita respectively. Also the consumption of the electricity will reach 27.19 TJ in 2050 which will be 0.24 GJ/capita.

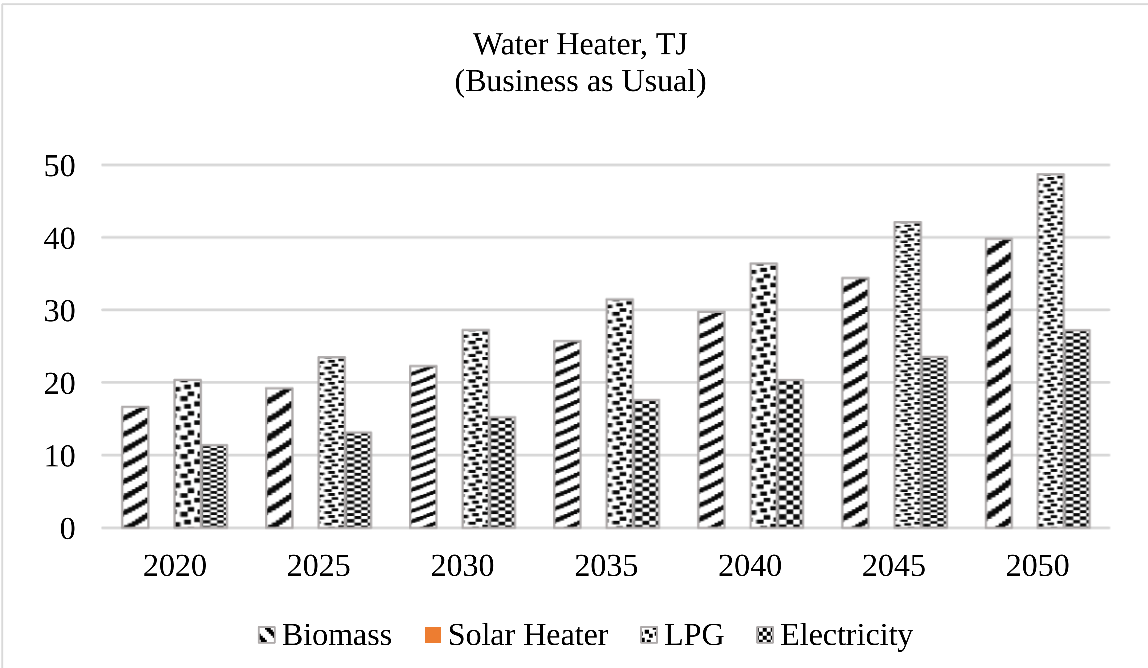

Figure 4.9 Fuels in Water heating – BAU

The usage of different electrical appliances and forecasting of their energy consumption up to 2050 is observed in figure 4.10 for business as usual scenario. Although the final energy consumption is found low, the largest power-consuming appliances are found to be Refrigerator and television. This is due to the inefficient CRT television used in the households of the municipality.

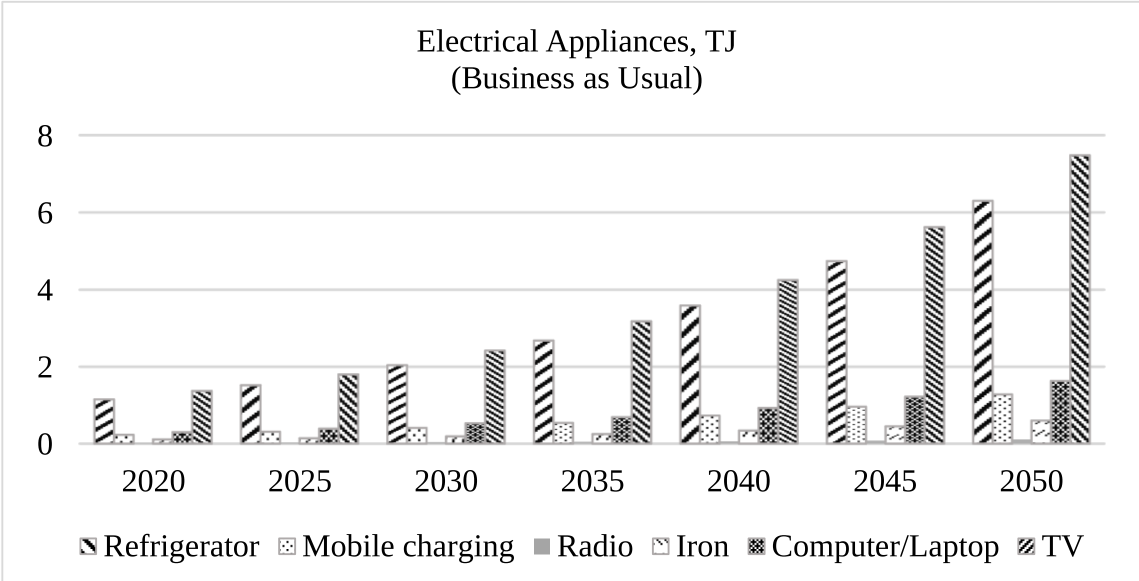

Figure 4.10 Energy consumptions for different electrical appliances – BAU

After the evaluation of energy demand for upcoming years for Business as usual scenario, the evaluation for emission is also performed for this scenario. Figure 4.11 shows that the major amount of the GHG emissions in the household sector of the municipality are observed for the cooking purpose because of the use of energy inefficient cooking technologies like firewood. The total emission will reach 9,316.19 tonnes of CO_2 equivalent in 2030 and 17,994.16 tonnes of CO_2 equivalent in 2050.

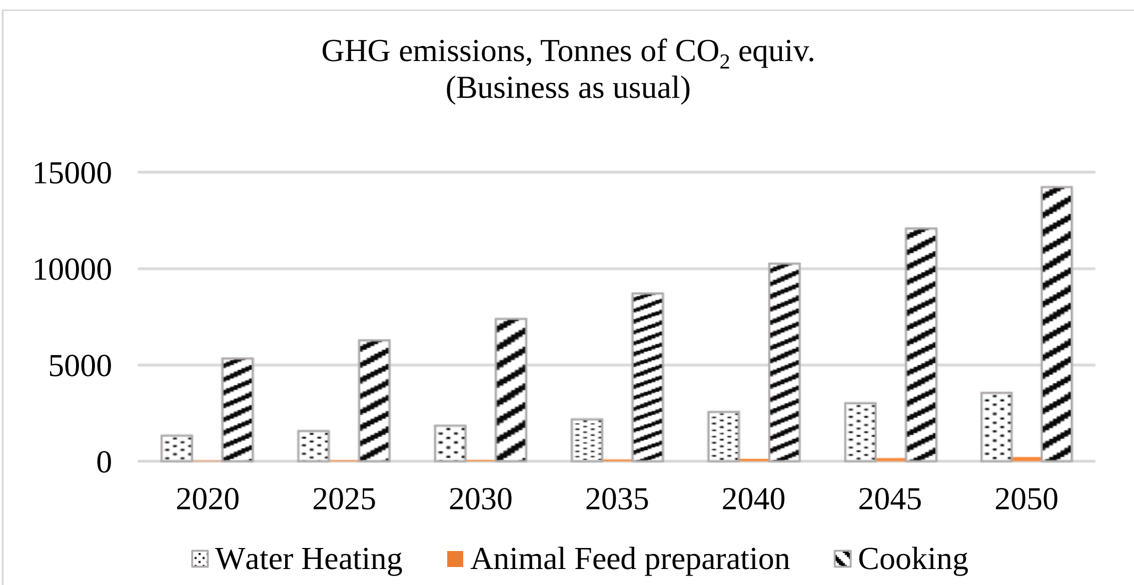

Figure 4.11 GHG emissions for different purposes – BAU

Figure 4.12 shows the bar chart for the per capita GHG emissions in kg of CO_2 at business as usual scenario. It will reach the value of 211.91 kg of CO_2 equivalent in the year 2030 and 287.22 kg of CO_2 equivalent in 2050. The value of per capita GHG emission is increasing in this scenario because of the increasing demand and no transformation to the cleaner fuels.

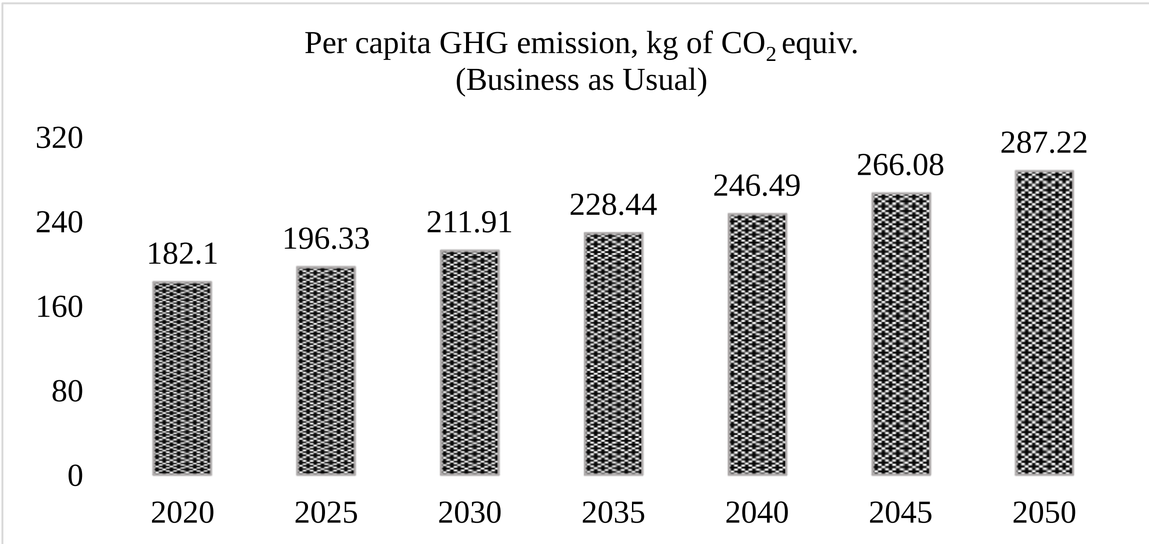

Figure 4.12 Per capita GHG emission – BAU

Figure 4.13 describes that major sources of environment loading is LPG. In business as usual scenario, the total environmental loading in cooking is found to be 1,744.71 tonnes of CO_2 equivalent in 2030 and 3,122.42 tonnes of CO_2 equivalent in 2050. This values are equivalent to 20.68 kg of CO_2 equivalent per capita in the year 2030 and 27.86 kg of CO_2 equivalent per capita in the year 2050.

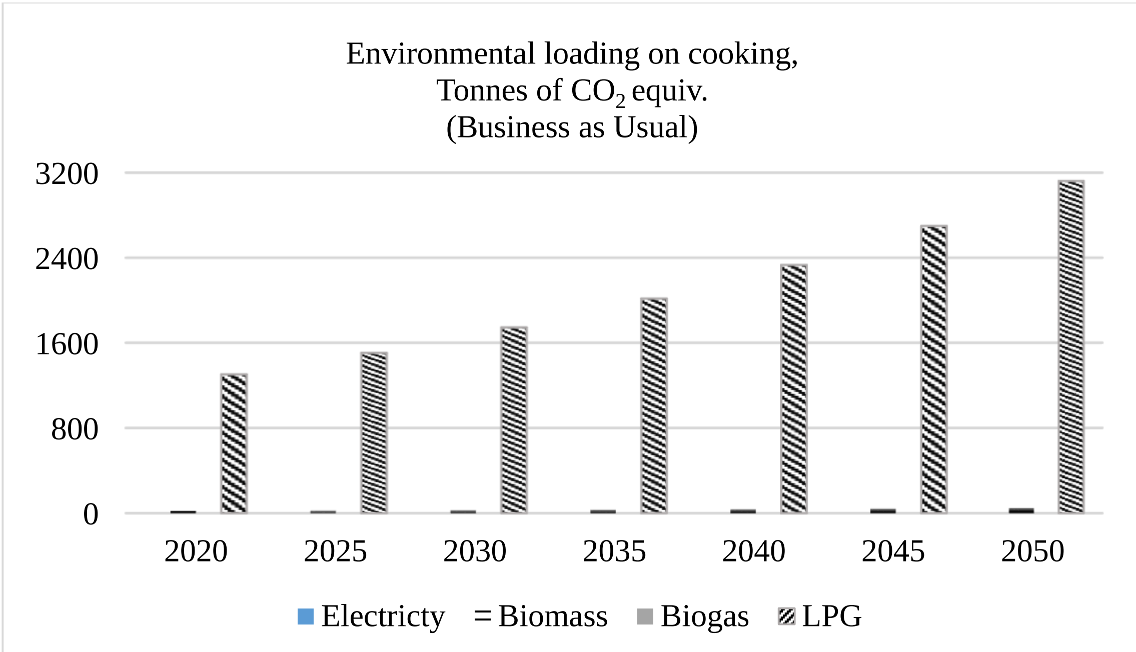

Figure 4.13 Environment Loading in cooking – BAU

Figure 4.14 depicts the loading of PM 2.5 material in the environment for business as usual scenario. The loading of PM 2.5 is projected to be 70 metric tonnes in 2030 and 122 metric tonnes in 2050. Similarly, the loading of Black carbon is projected to be 10 metric tonnes in 2030 and 20 metric tonnes in 2050.

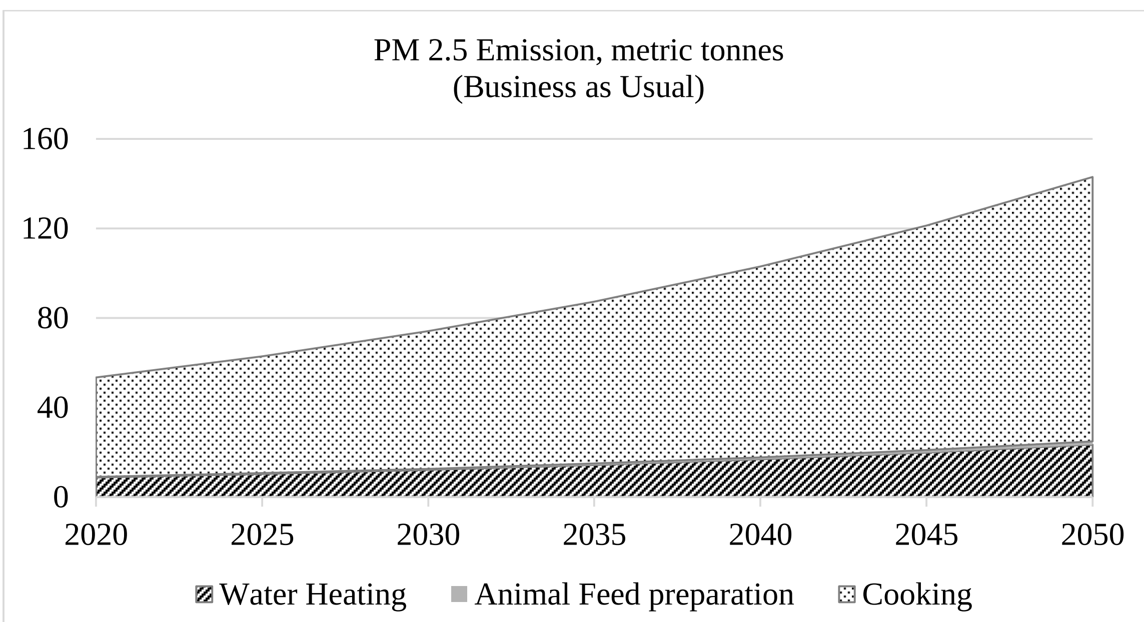

Figure 4.14 PM 2.5 loading – BAU

Figure 4.15 shows the loading of black carbon in the environment due to the different residential energy usage. The loading will increase to 10.17 metric tonnes in 2030 and 19.63 metric tonnes in 2050 with the major loading from cooking purpose.

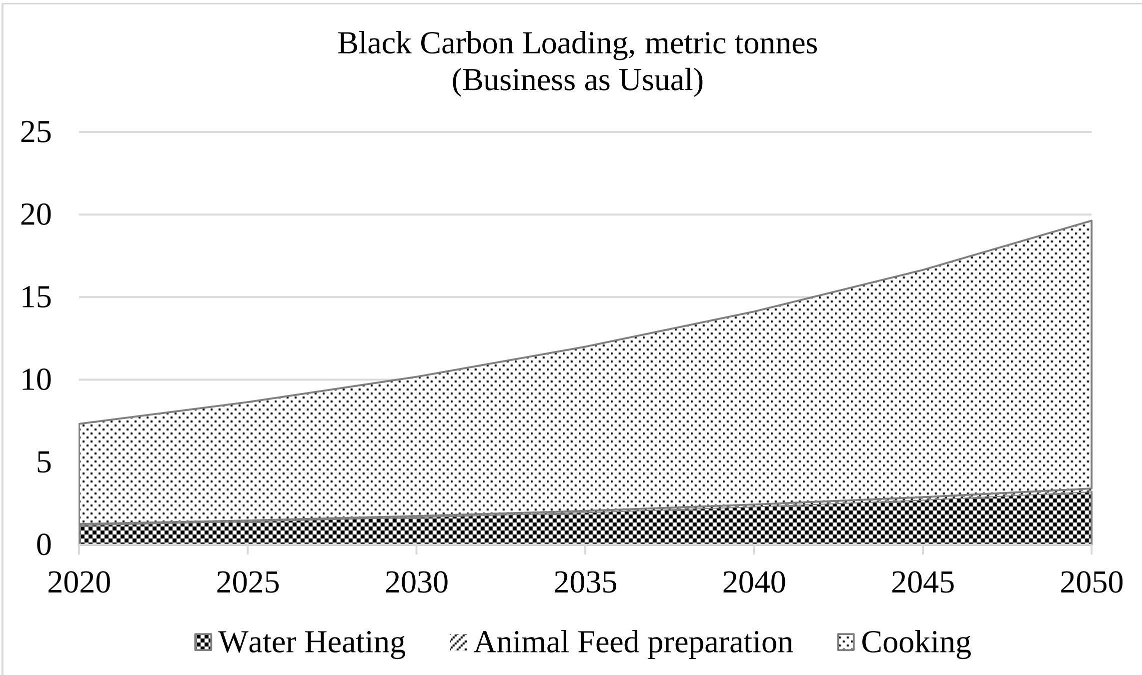

Figure 4.15 Black carbon loading – BAU

4.7. Sustainable Development Scenario

After carrying out the detailed analysis for the scenario of business as usual, the next step is started taking account of the various interventions in Neelakantha Municipality for the following years from 2020 to 2050 so as to develop the new scenario for the municipality stated as sustainable development scenario. In SUS scenario, the average yearly growth of GDP is taken to be 7% referencing to the sustainable development plan of Nepal by the Ministry of Urban Development of Nepal. The interventions of the energy technologies are conducted in various years referencing to the sustainable energy plan of Nepal. The modelling of the scenario is carried out in LEAP software and the analysis for the future demand in conducted for the scenario. The total demand for energy was observed from the year 2020 to the year of 2050 and from the results of LEAP, the relevant graphs are then extracted. The total energy demand will decrease slightly to 290 TJ until 2030 due to the interventions taken on the starting year 2020 and after that it will increase up to 532 TJ in

2050. In per capita figure, the energy consumption will reach 3.44 GJ/capita in 2030 and 4.75 GJ/capita in 2050. Figure 4.16 defines the energy demand for different household purposes for the scenario of sustainable development. In the year 2050, the total demand for this scenario is only 55% of that of BAU scenario.

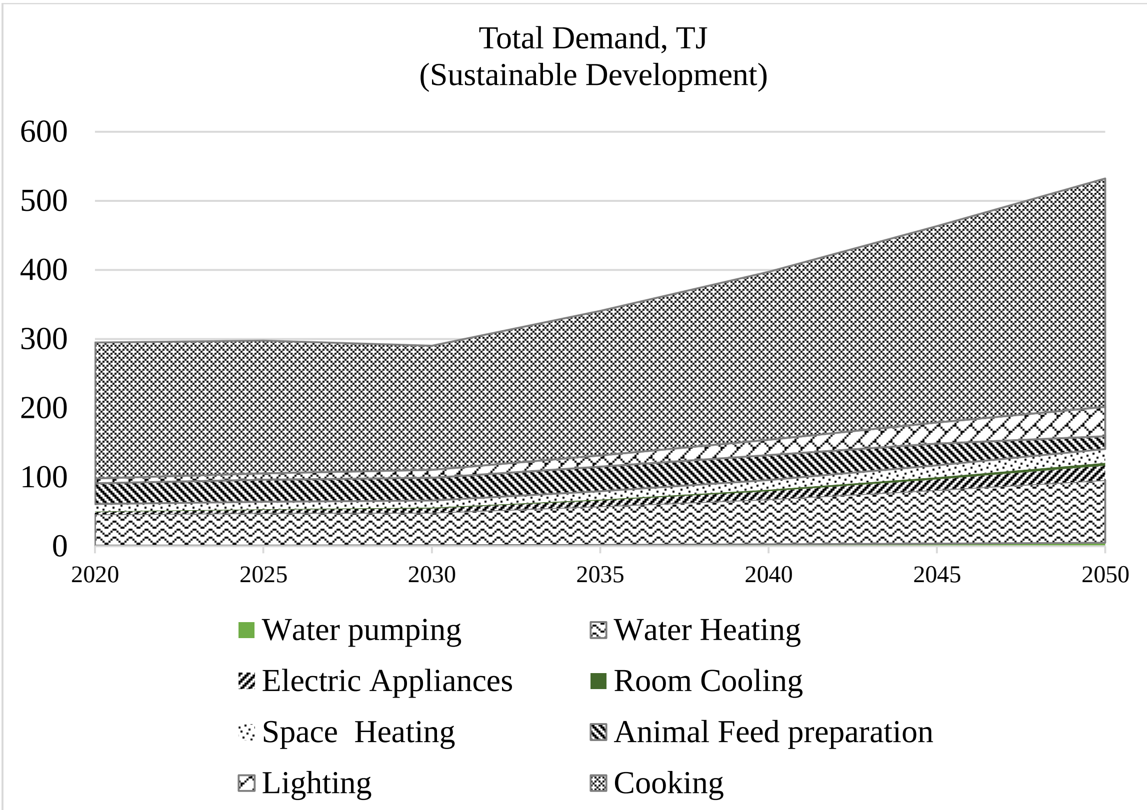

Figure 4.16 Demand for different household energy purposes – SUS

Figure 4.17 reflects the demand of different fuels for the following years up to. From the figure, the electricity usage will highly increase after 2030 leading to almost 92.39% of total energy usage being electricity in 2050. The use of LPG will totally diminish and the other conventional energy resources will decrease to 2.91% in the year 2050.

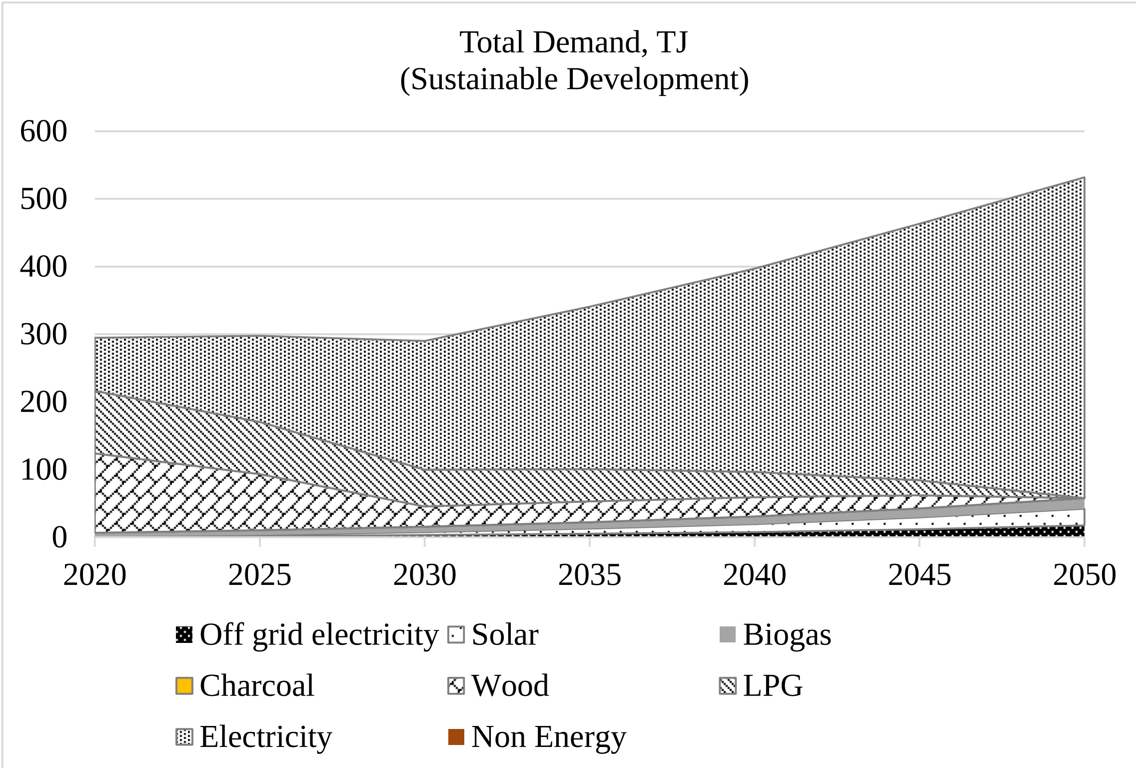

Figure 4.17 Demand for major fuels – SUS

Figure 4.18 depicts the distribution of different fuels used for the purpose of cooking for the scenario of sustainable development. Before the year 2030, the demand for LPG and firewood will be seen dominating. But after 2030, with the policy intervention in the municipality the electrical technologies will be extensively used for the cooking purpose which will gradually increase the share of electricity. After 2030, the consumption of LPG will drop down, and the consumption of firewood for cooking is strictly avoided. The electricity will be the dominant energy source for the household cooking purpose after year 2030.

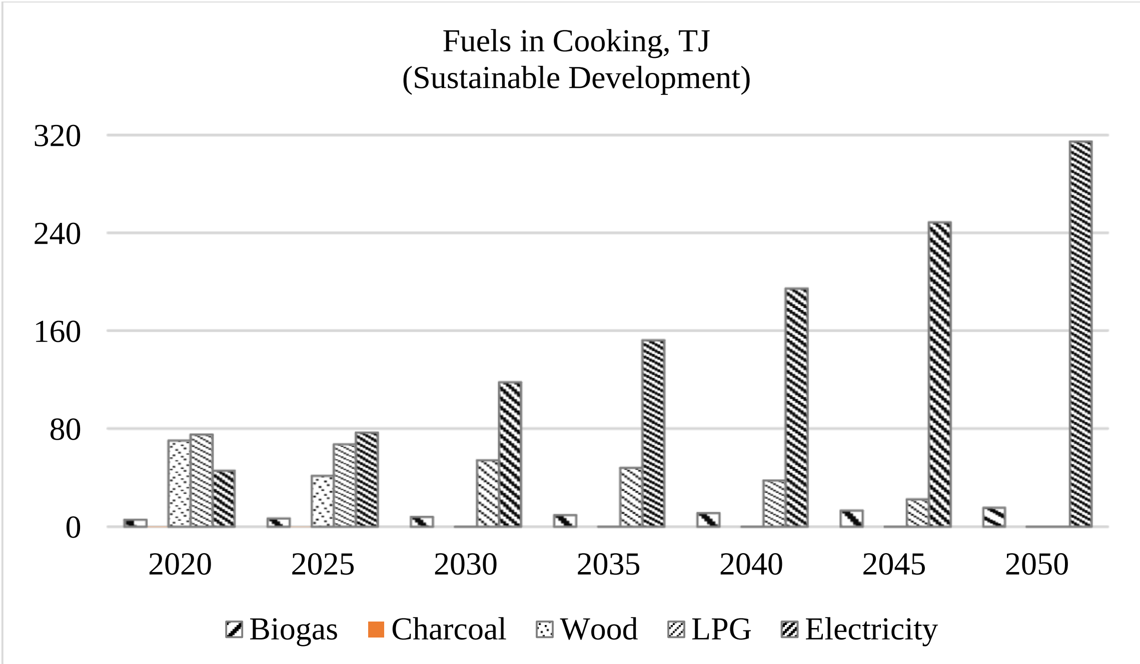

Figure 4.18 Fuels used for cooking purpose – SUS

The share of energy usage through the different luminaries used for the household lighting for SUS scenario of Neelakantha Municipality is presented in Figure 4.19. It is observed that the use of CFL is higher than other technologies like LED and Tube light in the initial years. But with the necessary interventions, the technologies of incandescent lamp, CFL and tube light are totally replaced with the highly efficient LED bulbs. In this scenario, some of the total lighting demand are also met with the solar LEDs with the integration of the solar home system in the households of the municipality.

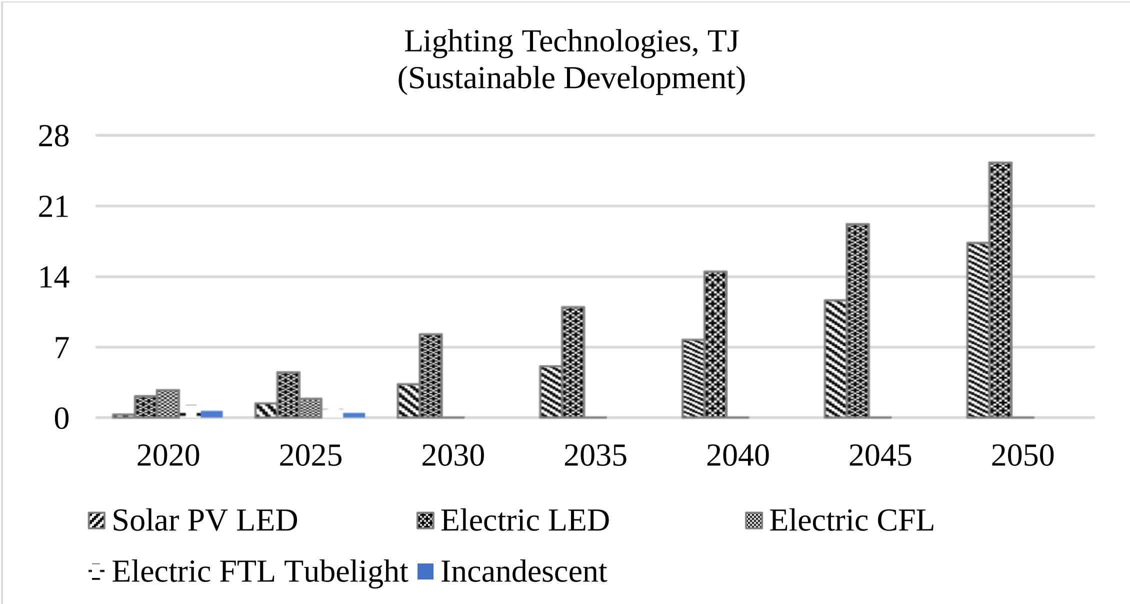

Figure 4.19 Lighting technologies – SUS

Figure 4.20 shows the fuel distribution for animal feeding purpose. In this scenario, with the replacement of animal feeding technology with electricity, the use of firewood will decrease after 2030. In the year 2050, the energy required for animal feeding will solely be fulfilled by electricity whose value will be 18.63 TJ and the per capita electricity consumption will be 0.166 GJ/capita.

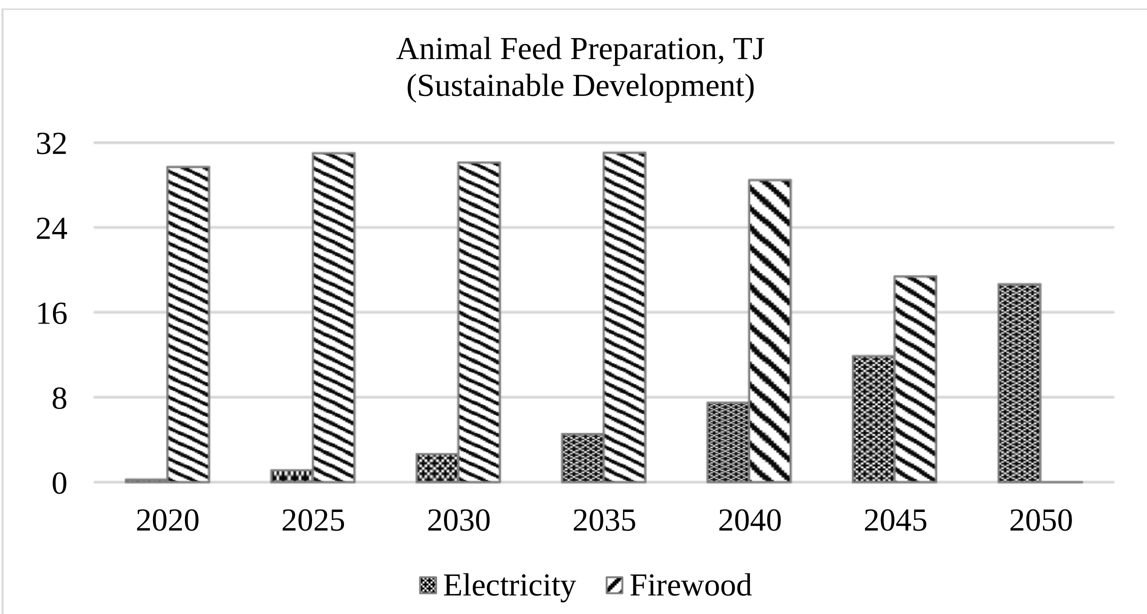

Figure 4.20 Fuels in Animal feeding – SUS

For feeding the domestic animals such as cows, buffaloes, goats found in the households of municipality, the use of firewood is seen to decrease slowly with the technology improvements in electricity. Firewood is still seen as the major source for animal feed preparation before 2050. For the space heating purpose, the use of firewood is replaced totally until 2030. The use of electricity is found to be 0.122 GJ/capita for year 2030 and 0.178 GJ/capita for the year 2050. Figure 4.21 presents the overall usage of energy for the purpose of space heating.

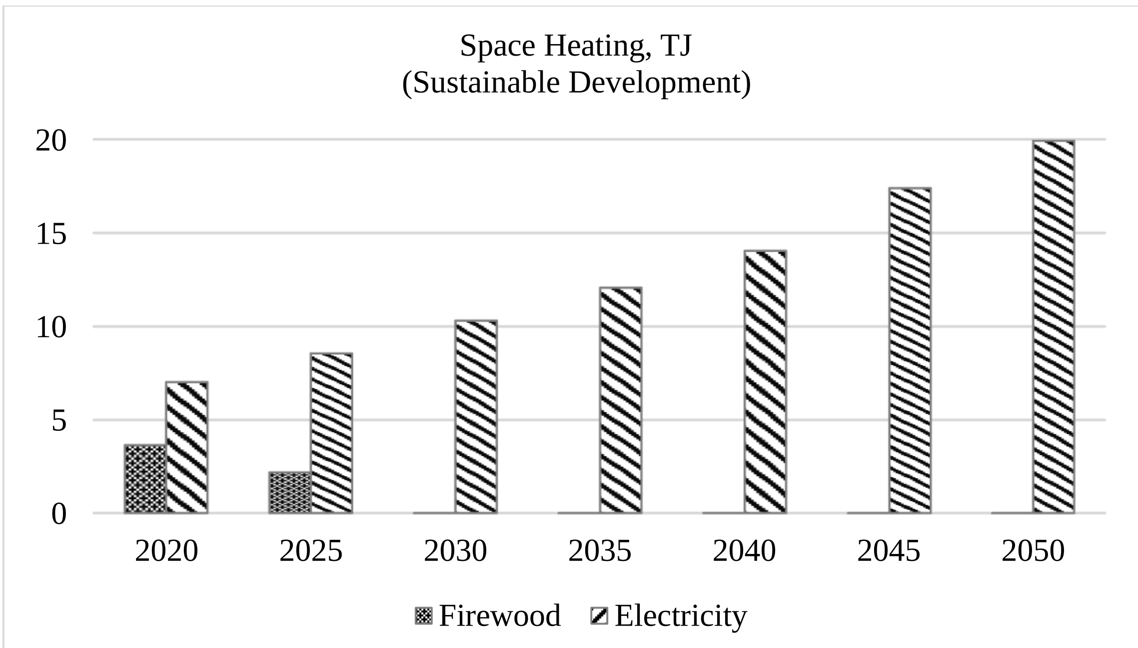

Figure 4.21 Fuels in Space heating – SUS

For the purpose of water heating, the usage of other inefficient technologies will reduce and the electrical water heating will be dominant after 2025. The use of biomass and LPG for water heating will be zero until the year 2030 and after that electricity will solely serve the demand. The consumption of electrical energy will reach 0.54 GJ/capita in 2030 and 0.725 GJ/capita in 2050.

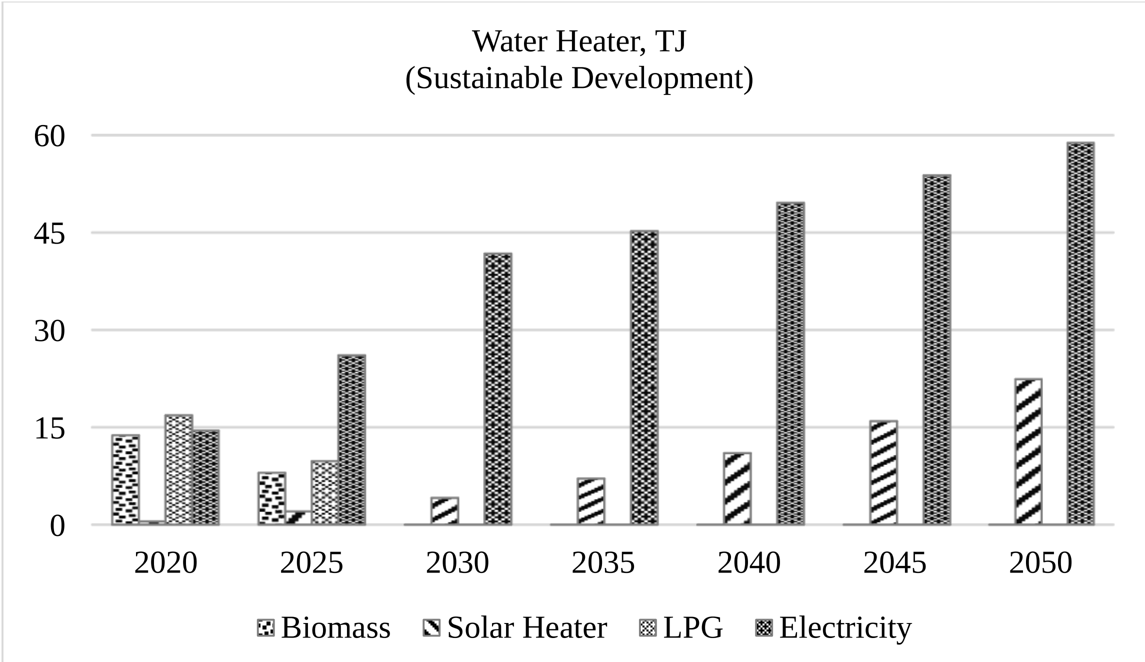

Figure 4.22 Fuels in Water heating – SUS

The use of different electrical appliances in the following years depends upon the changing lifestyle of the people in the location. The use of electrical appliances like Refrigerator, TV is expected to increase according to the increase in quality of life of the people. Figure 4.23 shows the energy consumption for different years for sustainable development scenario.

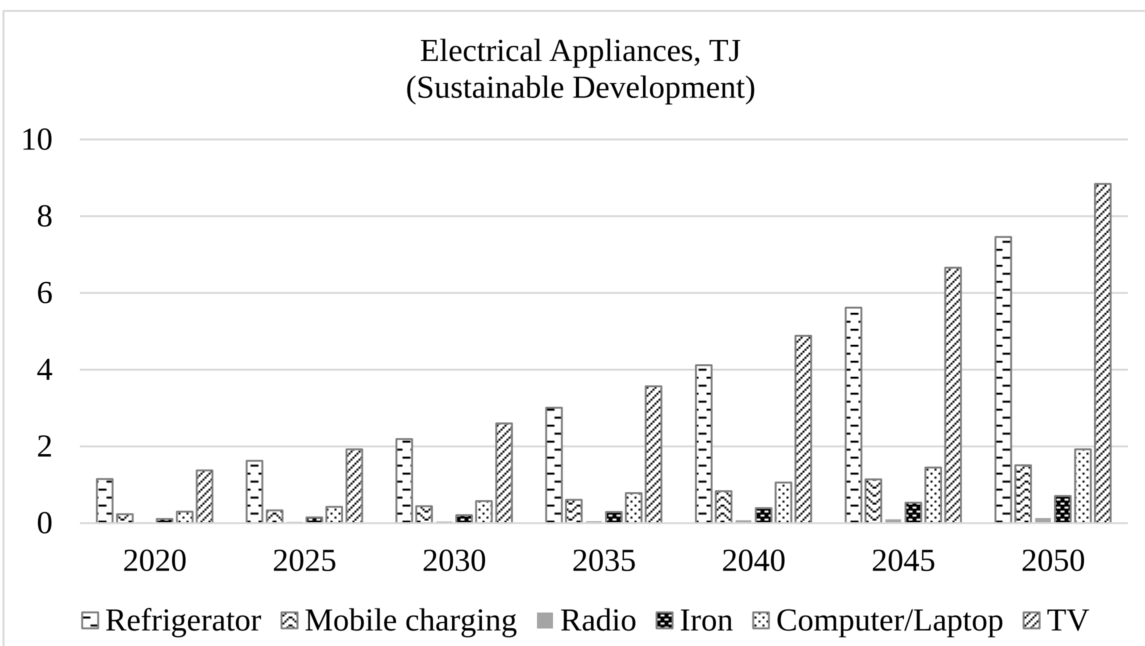

Figure 4.23 Energy consumptions for different electrical appliances – SUS

The emission analysis for the sustainable development scenario is carried out. Total GHG emission for different purposes are observed as shown in figure 4.24. With the intervention of cooking and water heating technologies with the highly efficient electrical apparatus, the GHG emission will go on decreasing. In the year 2030, it will decrease to 3,463.08 tonnes of CO_2 equivalent and in 2050, it will drastically reduce to 19.2 tonnes of CO_2 equivalent only.

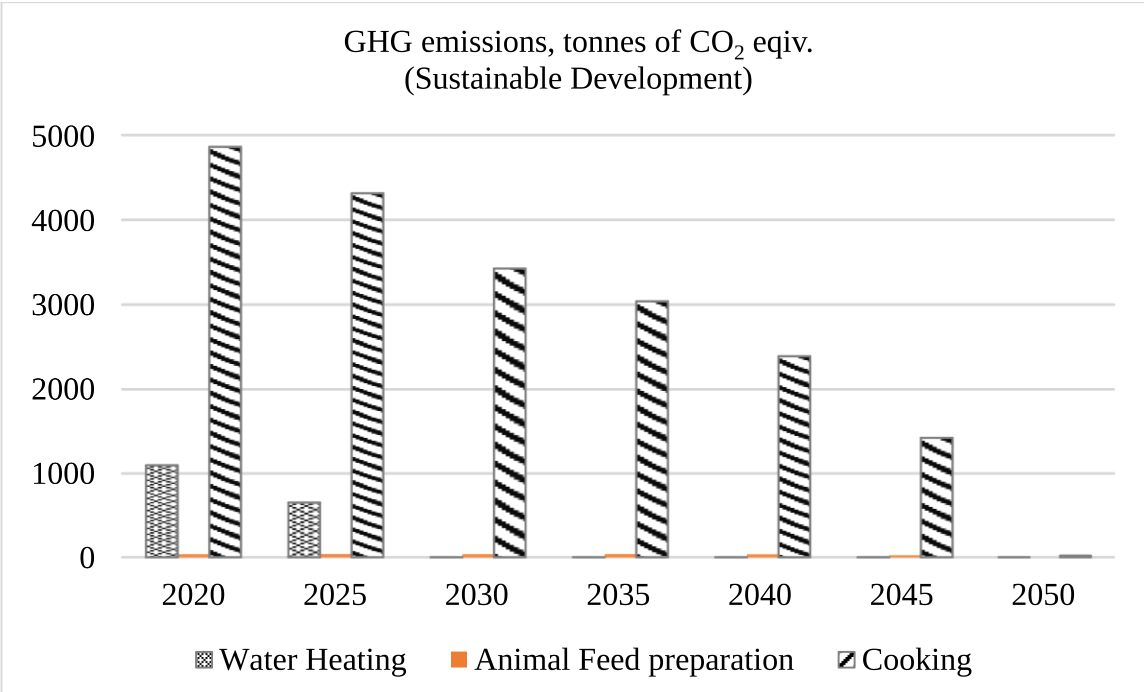

Figure 4.24 GHG emissions for different purposes – SUS

The major emission is observed in cooking in comparison to other household purposes. The graph in the figure 4.25 indicates the weight of CO_2 per capita equivalent of the GHG emissions over the years 2020 to 2050. The value of per capita GHG emission will reduce to 78.54 kg of CO_2 equivalent in the year 2030 and 0.31 kg of CO_2 equivalent in the year 2050.

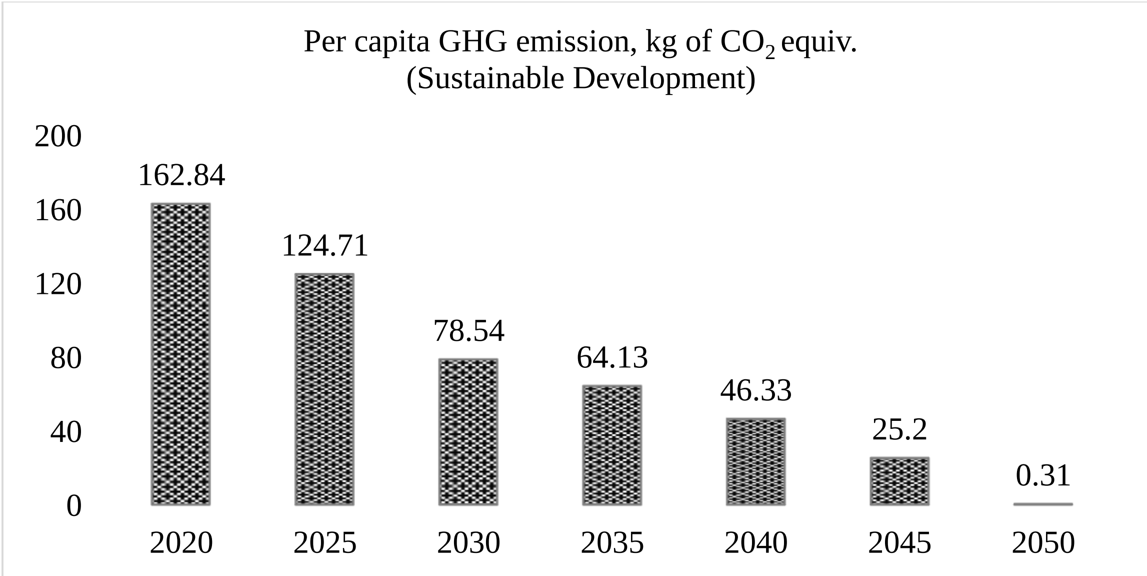

Figure 4.25 Per capita GHG emission – SUS

The environmental loading for cooking purpose which is high for LPG in the base year will significantly decrease down in the following years such that it will be zero in the year 2030 with the total replacement of LPG which is shown in figure 4.26. The transformation of the traditional cooking technologies with clean electrical energy will drastically decrease the loading in the environment.

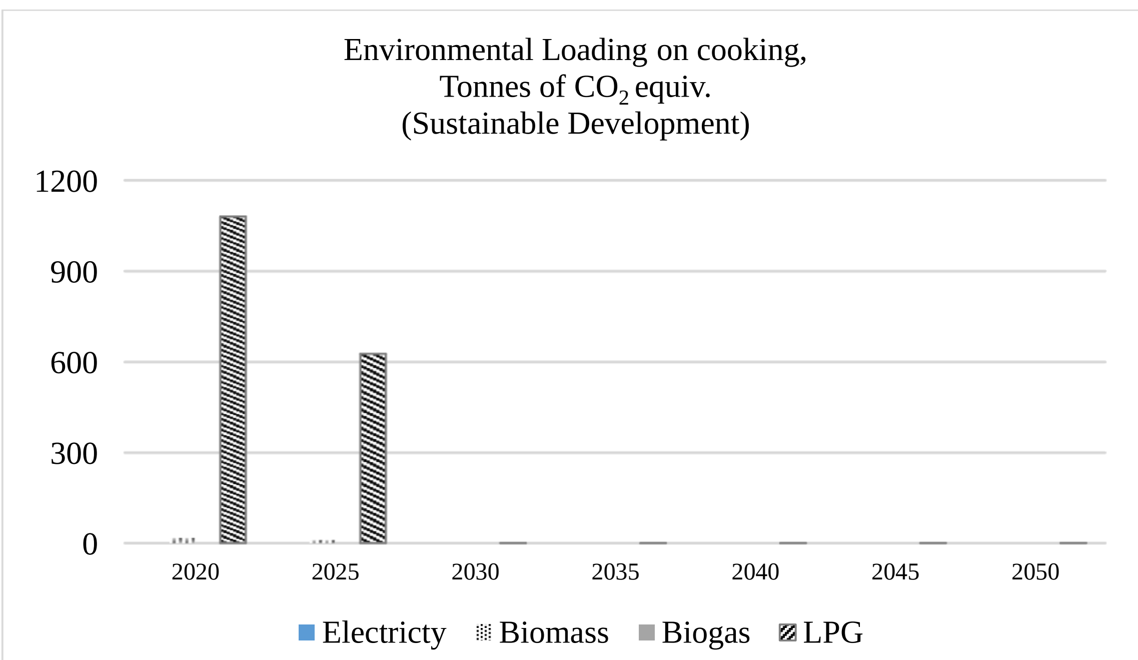

Figure 4.26 Environment Loading in cooking – SUS

Figure 4.27 show the quantity of PM 2.5 emission for up to 2050 in the sustainable development scenario. The total PM 2.5 emission is drastically reduced to 0.26 metric tonne in the year 2030 with the transformation of old technologies into the new electrified technologies. Major emission in households is seen to arrive from cooking and water heating.

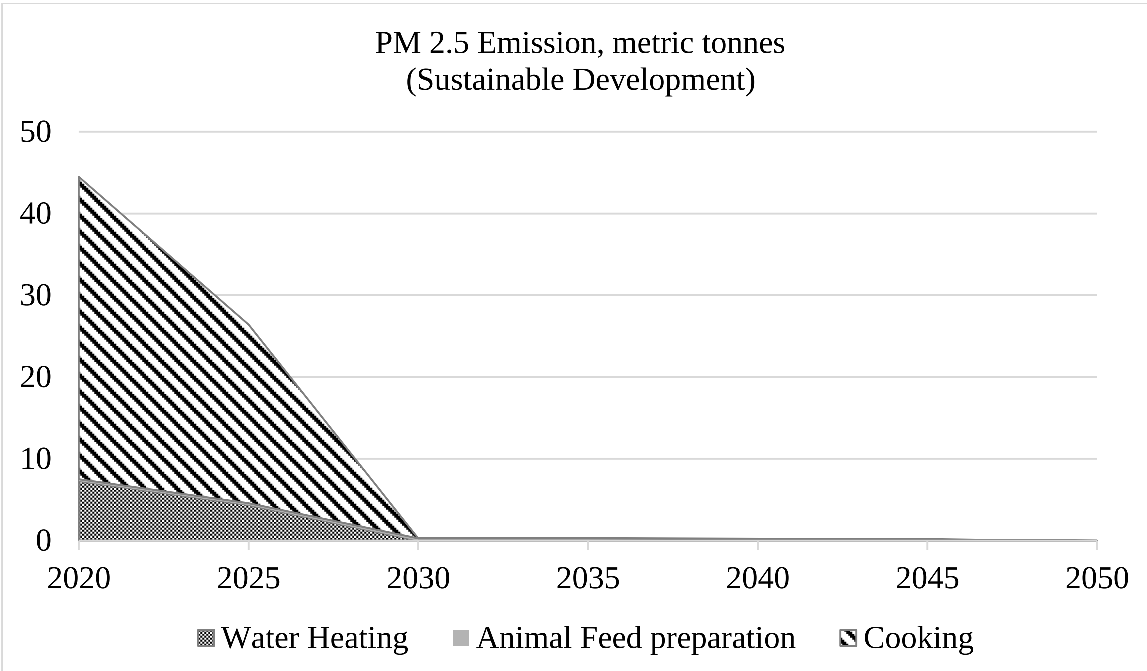

Figure 4.27 PM 2.5 loading - SUS

The amount of black carbon loading in the environment through the energy consumption in the municipality will reduce to 0.03 metric tonnes in 2030 from 6.1 metric tonnes in 2020 with the transformation of all emissive cooking stoves with the highly efficient electric cooking stove. The remaining small amount of Carbon loading will be because of the firewood used for animal feeding purpose.

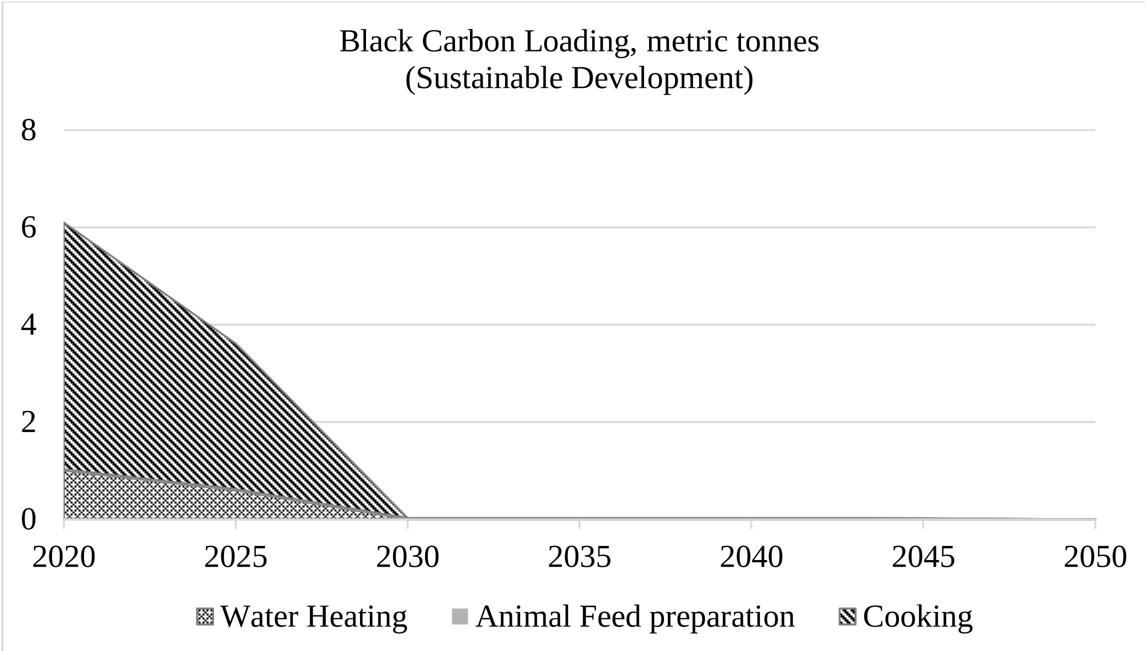

Figure 4.28 Black carbon loading – SUS

4.8. Comparison of BAU and SUS scenario

Table 4.4 shows the comparative analysis of total consumption of energy and GHG emission for two scenarios which are Business as usual and Sustainable Development. The energy demand is seen to be increasing for both scenarios. But the energy demand is found high for the Business as usual scenario because of the continuing the use of inefficient old technologies whereas, in sustainable development scenario, modern technologies with high energy efficiency are used. The transition of energy demand is seen in the year 2030. This is because of the interventions applied in the scenario according to the policy of sustainable development of the country. It can be concluded from this figure that the sustainable development scenario is better in context of the final energy demand. The detailed energy balance sheet for the year 2030 and 2050 for both Business as usual scenario and Sustainable Development scenario are shown in Appendix I. The respective Sankey diagram for the base year energy consumption and projected consumptions for 2030 and 2050 for both scenarios are shown in Appendix II. The GHG emission is calculated as the tonnes equivalent of CO_2. The emission of GHG in the base year more than 6,000 tonnes equiv. of CO_2. It is found to be increasing for the business as usual scenario due to the use of non-cleaner technology whereas it is seen decreasing in the case of sustainable development scenario as the pollutants are controlled by using modern cleaner technologies. The emission is 9316 and 3463 tonnes of CO_2 equiv. for the year 2030. For the end year 2050, the emission in BAU scenario is increased to the very high i.e. 17,994 whereas that in the SUS scenario is reduced to 19.2 tonnes of CO_2 equivalent.

Table 4.4 Final energy demand and emission of GHG for BAU and SUS scenario

Year	Final Energy Demand (TJ)		Final GHG Emission (Tonnes of CO_2 equivalent)	
	BAU	SUS	BAU	SUS
2020	313.6	295	6709.54	5995.39
2025	376.81	297.59	7907.48	5004.51
2030	438.19	290.19	9316.19	3463.08
2035	543.07	340.86	10983.67	3077.31
2040	655.47	397.17	12947.76	2426.08
2045	792.15	463.31	15260.32	1449.19
2050	958.61	532.05	17994.16	19.2

Since the LPG used for cooking purpose is imported from foreign countries a lot of economy is going outside. So LPG is one of the drivers of economy of the municipality. The GJ value of LPG contribution is converted to the price equivalent annualized cost with the annual discount rate of 6%. This annualized value is then plotted in graph to make comparison between two scenarios. For SUS scenario, the fuel import cost decreased slowly whereas increased to 328.73 million NRs. in the year 2050 for BAU whereas this value is seen to diminish in 2050 in SUS scenario as shown in figure 4.29.

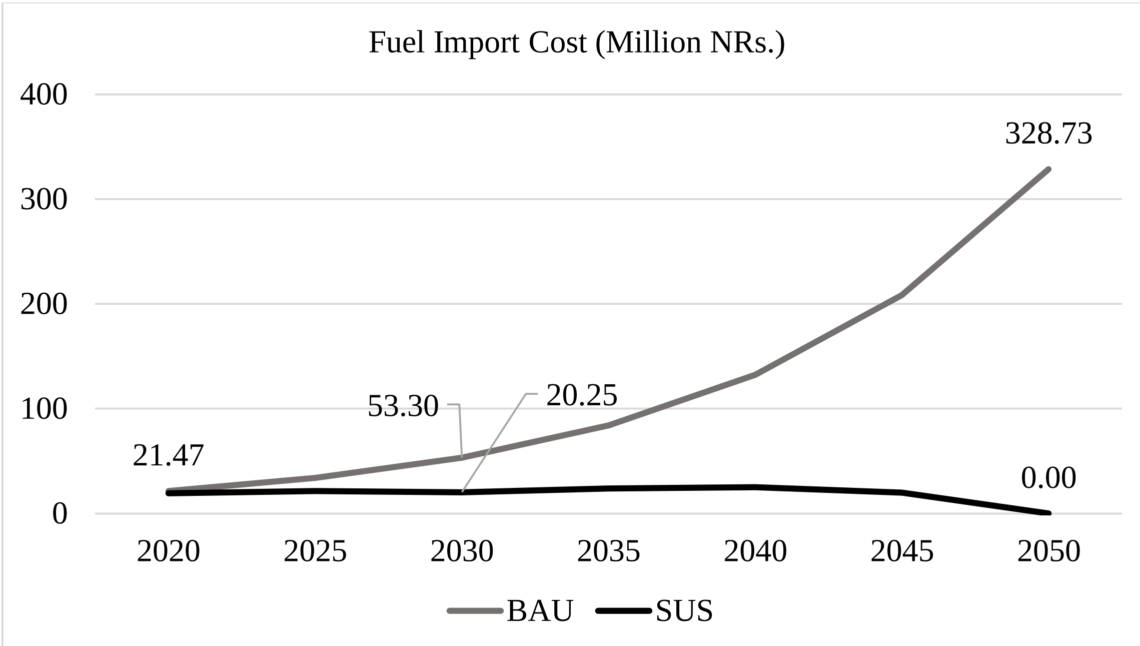

Figure 4.29 Fuel Import cost for BAU and SUS scenario

The energy indicators for the both scenarios are calculated. The per capita annual energy consumption will grow to 6.16 GJ in 2030 and 13.48 GJ in 2050 in Business as Usual Scenario. The total per capita consumption of electricity will raise to 352.60 kWh in 2030 and 840.16 kWh in 2050 in Business as Usual Scenario and similarly 744.01 kWh in 2030 and 1,851.79 kWh in 2050 in Sustainable Development Scenario as shown in figure 4.30.

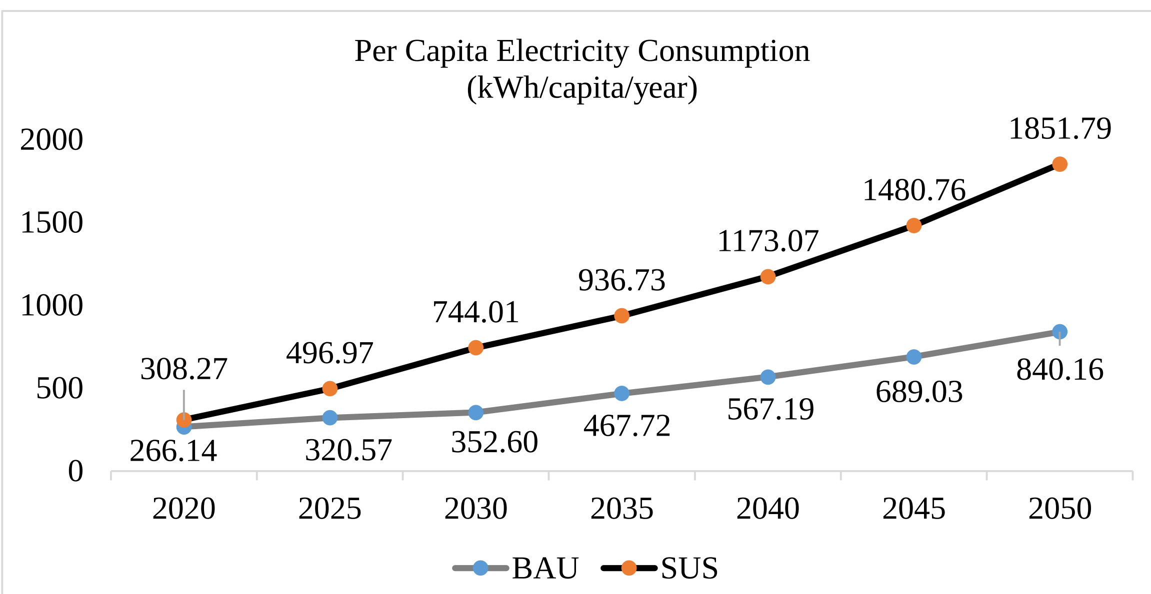

Figure 4.30 Per capita electricity consumption for BAU and SUS scenario

The share of electricity in total energy demand will only reach 22.44% in the year 2050 in Business as Usual scenario. This is because there is not any intervention of the conventional technologies with modern electrified technologies in this scenario. The per capita annual energy consumption is raised to be 4.08 GJ only in 2030 and 7.48 GJ only in 2050 in the Sustainable Development Scenario. The electricity share will reach 66.79% by 2030 and around 92.39% by 2050 in Sustainable Development scenario. The table 4.5 shows the values of energy indicators from 2020 to 2050 for Business as Usual as well as Sustainable Development Scenario.

Table 4.5 Energy Indicators for BAU and SUS Scenario

	GJ/capita	GJ/HH	Share of conventional Energy	Petroleum Share	Electricity Share	Electricity (kWh/ HH	Electricity (Res) kWh/capita	Electricity Wh per capita per day
Business as Usual Scenario								
2020	4.41	21.59	45.51%	32.75%	21.73%	1303.4	266.14	729.14
2025	5.3	25.94	46.12%	32.10%	21.79%	1570.01	320.57	878.29
2030	6.16	30.17	46.90%	32.49%	20.61%	1726.84	352.6	966.02
2035	7.63	37.39	47.06%	30.88%	22.05%	2290.65	467.72	1281.43
2040	9.21	45.13	47.71%	30.13%	22.16%	2777.78	567.19	1553.93
2045	11.14	54.54	48.38%	29.35%	22.27%	3374.49	689.03	1887.74
2050	13.48	66	49.00%	28.56%	22.44%	4114.65	840.16	2301.8
Sustainable Development Scenario								
2020	4.15	20.31	41.82%	31.15%	26.86%	1509.76	308.27	844.58
2025	4.18	20.49	30.15%	25.91%	43.24%	2433.9	496.97	1361.56
2030	4.08	19.98	13.12%	18.64%	66.79%	3643.78	744.01	2038.39
2035	4.79	23.47	11.87%	14.06%	71.86%	4587.62	936.73	2566.38
2040	5.58	27.35	9.96%	9.47%	77.58%	5745.09	1173.07	3213.89
2045	6.51	31.9	7.01%	4.81%	84.36%	7251.98	1480.76	4056.87
2050	7.48	36.63	2.91%	0.00%	92.39%	9069.09	1851.79	5073.39

4.9. Benefit Cost Analysis

Taking the account of per unit cost for each energy resources, the cumulative costs and benefits for business as usual scenario as well as sustainable energy scenario are evaluated in LEAP software. The per unit cost for firewood is taken to be 20 NRs. per kg according to the questionnaire survey in the municipality. The cost of LPG is taken to be 1500 NRs. cylinder containing 14.2 kg weight of LPG gas. The social discounting rate of 6% is used for the calculation of Net Present Value in both scenarios. Table 4.6 shows the Net present value cost for the implementation of strategies of Sustainable development in Neelakantha municipality in comparison to the business as usual scenario.

Table 4.6 Cumulative Cost and Benefit Analysis

	Net Present Value	
Cumulative Cost and Benefit Analysis	Business as Usual	Sustainable Development
Demand (Million NRs.)	2,114.51	7,156.01
Residential sector (Million NRs.)	2,114.51	7,156.01
Transformation (Million NRs.)	874.56	2,452.5
Transmission and Distribution (Million NRs.)	-	-
Grid electricity (Million NRs.)	874.56	2,394.79
Off grid electricity (Million NRs.)	-	57.7
Resources (Million NRs.)	11,229.34	2,827.7
Production (Million NRs.)	7,907.26	1,495.64
Imports (Million NRs.)	3,322.08	1,332.06
Exports (Million NRs.)	-	-
Unmet Requirements (Million NRs.)	-	-
Environmental Externalities (Million NRs.)	72.32	32.52
Non Energy Sector Costs (Million NRs.)	-	-
Net Present Value (Million NRs.)	14,290.74	12,468.73
GHG Emissions (Million Tonnes of CO_2 eqivalent)	0.37	0.11

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The baseline energy situation was analyzed after conducting the detailed household survey of Neelakantha Municipality. The final energy demand in the base year 2018 was found to be 292 TJ among which 38.9% share was from firewood and 34.3% from LPG. The share of electricity in total consumption of energy was 19.6% only. The mainly energy consuming area of households was observed in cooking meal which comprised 67.3% of the total consumption of energy in the municipality. From the detailed analysis of the base year situation of energy consumption in residential sector of Neelakantha Municipality, it was concluded that the consumption of firewood and LPG were prior which were comprising the major emission in the municipality. 33% of the total households of the municipality are supplied by 16 ampere fuse whereas the remaining are still using the 5 ampere fuse.

The consumption of energy in Business as usual scenario was increased to 438.19 TJ in 2030 and 958.61 TJ in the year 2050. Also the GHG emission in the year 2030 was calculated as 9,316.19 tonnes of CO_2 equivalent in the year 2030 and 17,994.16 tonnes of CO_2 equivalent in 2050. The net present value of the cost of energy for upto 2050 in business as usual scenario was calculated to be 14,290.74 Million NRs. as per the money value of base year 2018.

After the implementation sustainable development intervention, the future demand was seen to be increased significantly with the consumption of electrical energy from national grid supply in the following years. The cooking technology was to be replaced by electrical cooker. It was seen that the total electricity consumption could cover 89% of final energy usage in the year 2050. The final energy consumption in the year 2030 was calculated as 290.19 TJ and that in the year 2050 was found to be 532.05 TJ. Also the GHG emission in the year 2030 was reduced to 3,463.08 tonnes of CO_2 equivalent in the year 2030 and 19.2 tonnes of CO_2 equivalent in the year 2050. The net present value of the cost of energy for upto 2050 in sustainable development scenario was calculated to be 12,468.73 Million NRs. as per the money value of base year 2018.

Implementing the sustainable development strategies in the household sector of Neelakantha Municipality, the total energy consumption faced a large reduction of 426 TJ in the final energy consumption. It is beneficial as this energy could be utilized for expanding the industrial sectors in the municipality. The GHG emission of 17,994 tonnes of CO_2 equivalent in the year 2050 in BAU scenario was only observed 19.2 tonnes for sustainable development scenario which is very negligible as in comparison to the scenario of business as usual. This drastic reduction is because of the utilization of non-emissive and efficient electrical technologies in the Sustainable development scenario.

The consumption of electricity was to seen to be increased to 744 kWh/capita with total share of 66.79% in 2030 and 1,851.79 kWh/capita with total share of 92.39% in 2050. This shows that the sustainable development strategies are responsible for the electrification of the households of the Municipality which could replace the traditional fuels and appliances with the highly efficient electrified technologies. The share of conventional energy resources was seen to reduce to 2.91% and that of petroleum was seen to reduce to 0% in the year 2050.

The cumulative cost benefit analysis of both scenarios showed that it is beneficial to employ the strategies for the sustainable development in Neelakantha municipality since the Net Present Value Cost for Sustainable Development Scenario is observed to be lesser than that for Business as usual scenario by 1,822 Million NRs as per the money value of the base year 2018. This is because of the reduction of per capita energy usage of conventional energy sources such as biomass and LPG in Sustainable Development scenario.

In this way, the intervention of the technologies for sustainable development planning is observed to be beneficial in every aspect. i.e. Final Energy Demand aspects, GHG Emission aspects and Economic aspects. Hence, this study strongly recommends the sustainable development plan to the local government of Neelakantha Municipality.

5.2. Recommendations

This study was limited to only the household sector of Neelakantha Municipality. There are a lot of Municipalities whose energy planning are not done yet. The further research might be carried out in the near future with referencing to this study.

i. In this research, only household demand is analyzed. Further research may include other energy consuming sectors of the municipality such as industrial, commercial and transport sector, which can provide the better understanding of the energy consumption in Neelakantha Municipality.
ii. In this study, the data for the analysis were collected from the sample survey with the respondents. To find out the more accurate value of the energy situation, one can conduct the analysis with CBS report which will be published after the population census in following year 2021.
iii. The federal and provincial government may plan for hydropower projects inside the boundary of municipality based upon the requirement of electrical energy in the further years so as to make the Municipality independent for the electricity production and consumption.
iv. The local government may look for assistance and subsidies from governmental and non-governmental agencies to install small alternative energy production plants inside the boundary of the municipality and may also promote the production of renewable energies from solar energy or biogas in the households of the municipality.

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APPENDIX I: Energy Balances

Business as Usual Scenario (2030)

	Electricity	LPG	Wood	Charcoal	Biogas	Hydro	Total
Production	-	-	197.05	-	7.87	127.98	332.91
Imports	-	142.37	-	0.59	-	-	142.96
Exports	-	-	-	-	-	-	-
Total Primary Supply	-	142.37	197.05	0.59	7.87	127.98	475.87
Off grid electricity	-	-	-	-	-	-	-
Grid electricity	108.78	-	-	-	-	- 127.98	- 19.20
Transmission and Distribution	-18.49	-	-	-	-	-	- 18.49
Total Transformation	90.29	-	-	-	-	- 127.98	- 37.69
Residential sector	90.29	142.37	197.05	0.59	7.87	-	438.18
Total Demand	90.29	142.37	197.05	0.59	7.87	-	438.18

Sustainable Development Scenario (2030)

	Electricity	LPG	Wood	Biogas	Solar	Hydro	Off grid Elec.	Total
Production	-	-	30.1	7.95	8.00	275.32	-	321.4
Imports	-	54.1	-	-	-	-	-	54.08
Exports	-	-	-	-	-	-	-	-
Total Primary Supply	-	54.1	30.1	7.95	8.00	275.32	-	375.47
Off grid electricity	-	-	-	-	-3.78	-	3.78	-
Grid electricity	234.02	-	-	-	-	-275.32	-	-41.30
Transmission and Distribution	-43.50	-	-	-	-	-	- 0.47	-43.98
Total Transformation	190.52	-	-	-	-3.78	-275.32	3.31	-85.28
Residential sector	190.52	54.1	30.1	7.95	4.22	-	3.31	290.2
Total Demand	190.52	54.1	30.1	7.95	4.22	-	3.31	290.2

Business as Usual Scenario (2050)

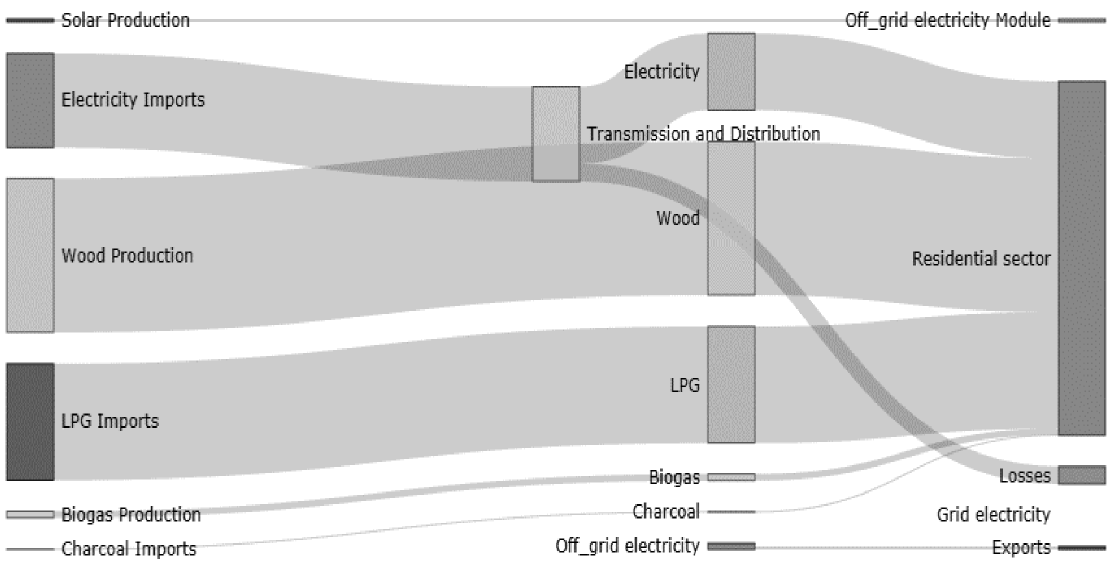
	Electricity	LPG	Wood	Charcoal	Biogas	Hydro	Total
Production	-	-	453.41	-	15.14	304.95	773.50
Imports	-	273.77	-	1.14	-	-	274.91
Exports	-	-	-	-	-	-	-
Total Primary Supply	-	273.77	453.41	1.14	15.14	304.95	1,048.41
Off grid electricity	-	-	-	-	-	-	-
Grid electricity	259.21	-	-	-	-	-304.95	-45.74
Transmission and Distribution	-44.07	-	-	-	-	-	-44.07
Total Transformation	215.14	-	-	-	-	-304.95	-89.81
Residential sector	215.14	273.77	453.41	1.14	15.14	-	958.60
Total Demand	215.14	273.77	453.41	1.14	15.14	-	958.60

Sustainable Development Scenario (2050)

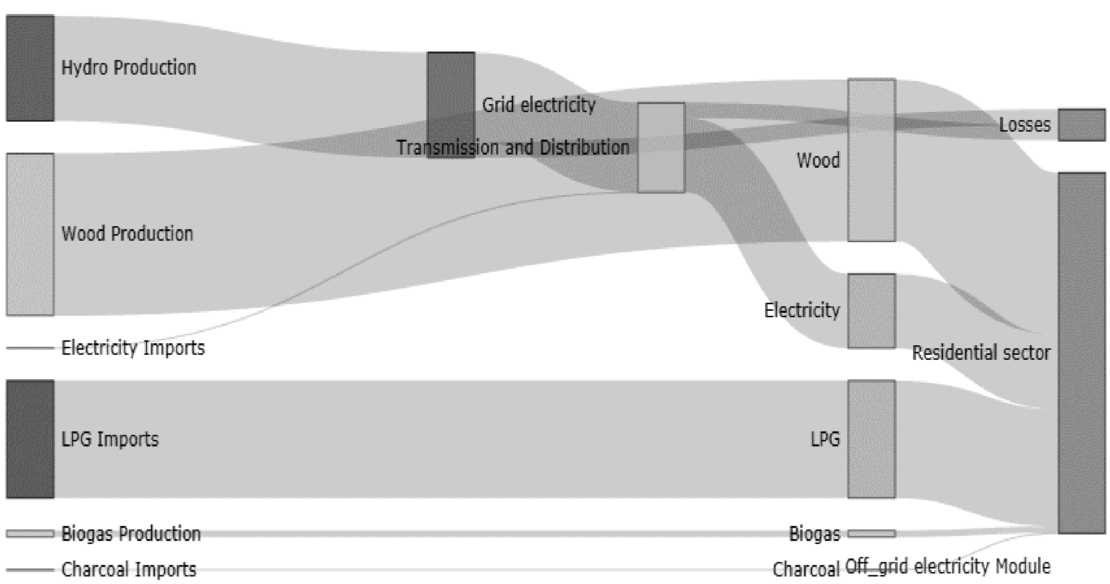
	Electricity	Biogas	Solar	Hydro	Off grid Elec.	Total
Production	-	15.48	44.84	685.27	-	745.59
Imports	-	-	-	-	-	-
Exports	-	-	-	-	-	-
Total Primary Supply	-	15.48	44.84	685.27	-	745.59
Off grid electricity	-	-	-19.82	-	19.82	-
Grid electricity	582.48	-	-	-685.27	-	-102.79
Transmission and Distribution	-108.28	-	-	-	-2.48	-110.76
Total Transformation	474.19	-	-19.82	-685.27	17.34	-213.55
Residential sector	474.19	15.48	25.02	-	17.34	532.04
Total Demand	474.19	15.48	25.02	-	17.34	532.04

APPENDIX II: Sankey Diagrams

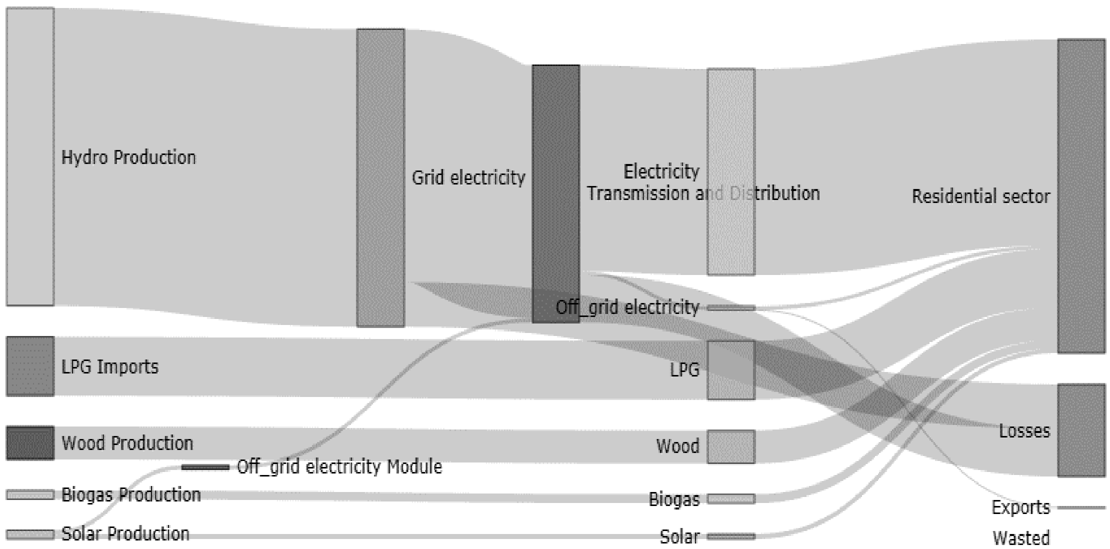
Base Year (2018)



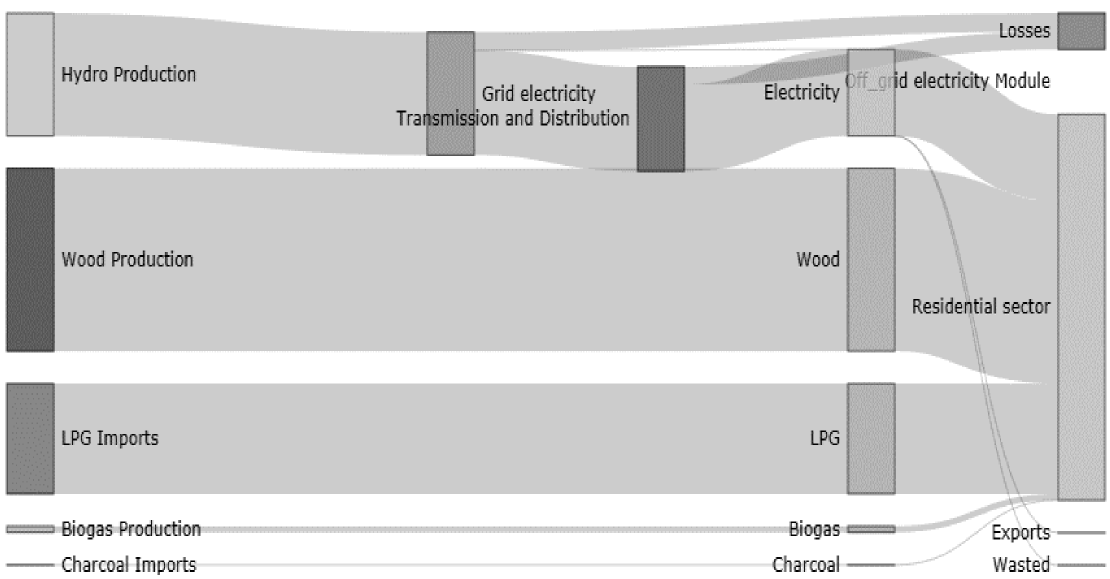
Business as Usual Scenario (2030)



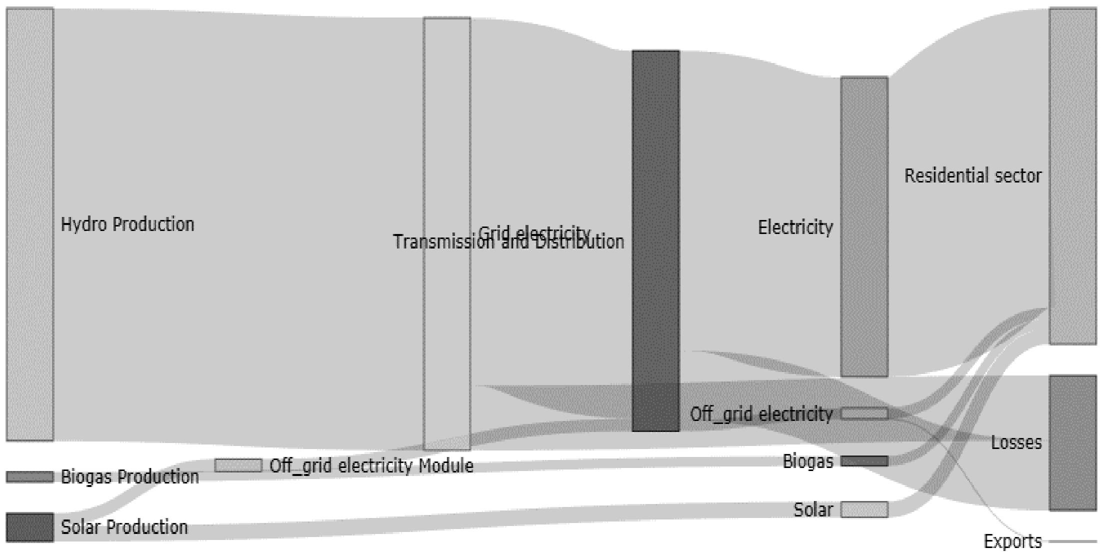
Sustainable Development Scenario (2030)



Business as Usual Scenario (2050)



Sustainable Development Scenario (2050)



APPENDIX III: Parameters for Analysis

Fuel Cost (2018)

Fuel type	Quantity	Price
LPG gas	1 cyl. = 14.2 kg	1,500 NRs.
Firewood	1 kg	20 NRs.

Lighting Technology Cost (2018)

Type	Wattage	Price
Incandescent bulb	100 W	40 NRs.
Fluorescent tubelight	40 W	300 NRs.
CFL	15 W	250 NRs.
LED bulb	7 W	350 NRs.

Cooking Technology Cost (2018)

Type	Size	Price
LPG stove	Medium	4,000 NRs.
Improved Cook Stove	Medium	2,000 NRs.
Induction Stove	Medium	6,000 NRs.

Fuel Efficiencies

Fuel types	Efficiencies
Firewood	10%
LPG	65%
Charcoal	45%
Biogas	60%

Lighting Efficiencies

Luminaries type	Efficiencies
Incandescent Lamp	13%
Fluorescent Tube light	56.5%
Compact Fluorescent Lamp	64%
LED Lamp	80%

Economic values

Per capita income from Survey data	83,116 NRs.
Population	71,131
Percapita Income (Dhading) (NPC, 2014)	982 US$
GDP of Neelakantha, 2018 (calculated)	82.94 million US$

Growth rates

Discount Rate	6.00%
Population Growth	1.43%
GDP Growth (BAU)	4.60%
GDP Growth (SUS)	7.00%

Final Energy Intensity Distribution (Business as Usual)

	Cooking (TJ)	Water Heating (TJ)	Water Pumping (TJ)	Lighting (TJ)	Space Heating (TJ)	Electrical Appliances (TJ)	Others (TJ)
2020	1.31	0.37	0.00	0.06	0.09	0.03	0.03
2025	1.44	0.41	0.00	0.07	0.10	0.03	0.04
2030	1.57	0.45	0.00	0.09	0.11	0.04	0.05
2035	1.73	0.49	0.01	0.11	0.12	0.05	0.06
2040	1.89	0.54	0.01	0.14	0.13	0.06	0.07
2045	2.08	0.59	0.01	0.17	0.14	0.08	0.09
2050	2.28	0.65	0.01	0.21	0.16	0.09	0.11

Final Energy Intensity Distribution (Sustainable Development)

	Cooking (TJ)	Water Heating (TJ)	Water Pumping (TJ)	Lighting (TJ)	Space Heating (TJ)	Electrical Appliances (TJ)	Others (TJ)
2020	1.31	0.37	0.00	0.06	0.09	0.03	0.03
2025	1.44	0.41	0.00	0.08	0.10	0.03	0.04
2030	1.59	0.45	0.00	0.10	0.11	0.04	0.05
2035	1.75	0.50	0.01	0.12	0.12	0.05	0.06
2040	1.92	0.55	0.01	0.16	0.13	0.07	0.08
2045	2.12	0.61	0.01	0.20	0.15	0.09	0.10
2050	2.33	0.67	0.01	0.26	0.16	0.11	0.13

APPENDIX IV: Questionnaire for Survey

Section 1: General Information of the Respondent

Full name of Family Representative	
Mobile Number	
Gender	
Age	
Ethnicity	
Number of Family members	
Main Occupation	
Estimated Yearly Income	

Section 2: Information on Energy Usage

	Sources	**Average usage per month**	
Sources of Energy used in Lighting	National Electricity grid		
	Mini/Micro/Pico Hydro power		
	Solar Home System		
	Solar Micro Grid		
	Wind Power		
	Solar Wind Micro Grid		
	Battery Operated Lamp		
	Kerosene		
	Others (Specify)		
	Lamp Type	**Number**	**Usage Hours**
Types of Lamps	LED		
	CFL		
	Incandescent		
	Others (Specify)		
	Electrical Appliances Types	**Number**	**Usage Hours**
Electrical Appliances operating now	TV		
	Radio		
	Computer/Laptop		
	Refrigerator		
	Rice Cooker		
	Fan		
	Water pump		
	Microwave Oven		
	Washing Machine		
	Iron		

	Induction Heater		
	Mobile Phone		
	Air Conditioner		
	Others (Specify)		
	Electrical Appliances Types	**Planning to use? (Yes or No)**	
Electrical Appliances you wish to use in near future	TV		
	Radio		
	Computer/Laptop		
	Refrigerator		
	Rice Cooker		
	Fan		
	Water pump		
	Microwave Oven		
	Washing Machine		
	Iron		
	Induction Heater		
	Mobile Phone		
	Air Conditioner		
	Others (Specify)		
	Source	**Quantity**	**Monthly Expenses**
Source used to cook meal	Leaf Litter		
	Animal Dung		
	Firewood		
	Briquette		
	Kerosene		
	LPG gas		
	Biogas		
	Isolated hydropower		
	National grid line		
	Others(Specify)		
	Source	**Planning to use? (Yes or No)**	
Cooking Technologies you wish to use in near future	Mud ICS		
	Rocket Stove		
	Metallic ICS		
	Briquette Stove		
	Kerosene Stove		
	LPG gas		
	Biogas		
	Electrical Stove		
	Others(Specify)		

	Source	Quantity	Monthly Expenses
Source used for Water Heating	Source 1 (Specify)		
	Source 2 (Specify)		
	Source	**Planning to use? (Yes or No)**	
Water Heating Technology to use in near future	Technology 1 (Specify)		
	Technology 2 (Specify)		
	Source	**Quantity**	**Monthly Expenses**
Source used for Space Heating	Source 1 (Specify)		
	Source 2 (Specify)		
	Source	**Planning to use? (Yes or No)**	
Space Heating Technology to use in near future	Technology 1 (Specify)		
	Technology 2 (Specify)		
	Source	**Quantity**	**Monthly Expenses**
Source of cooking for Income Generation Activities	Source 1 (Specify)		
	Source 2 (Specify)		
	Source	**Quantity**	**Monthly Expenses**
Source of Cooking Animal Meal	Source 1 (Specify)		
	Source 2 (Specify)		

Section 3: Information on Energy Technologies

	Stove Type	Use of Cook Stove
Available Cook Stoves and their uses	Traditional Cook Stove	
	Husk Cook Stove	
	Improved Cook Stove	
	Improved Metallic Cook Stove	
	Kerosene Cook Stove	
	Biogas	
	Electrical Heater	
	Rice Cooker	
	LPG Stove	
	Others (Specify)	

	Source of Firewood	**Time required**	**Distance**
From where is firewood collected?	Community forest		
	Own Farm		
	Others (Specify)		
Responsibility to collect firewood	Who is the responsible person to collect firewood?	Woman/Man/Children	
	Questions	**Answers**	
Use of Improved Cookstove	Are you using?		
	Are you interested to use?		
	Can you invest to install?		
	What type of support do you expect to install?		
	How much can you invest to install?		
	How is the performance of installed?		
	Where do you take service when it faces problem?		
Use of Biogas Plant	Are you using?		
	Are you interested to use?		
	Can you invest to install?		
	What type of support do you expect to install?		
	How much can you invest to install?		
	How is the performance of installed?		
	Where do you take service when it faces problem?		
	Who fill up dung in Biogas Plant?		
Use of Solar Home System	Are you using?		
	Are you interested to use?		
	Can you invest to install?		
	What type of support do you expect to install?		
	How much can you invest to install?		
	How is the performance of installed?		
	Where do you take service when it faces problem?		

Use of National Electricity Grid	How many hours of electricity supply you get in a day?	
	How many hours of electricity supply you get in evening?	
	Is the power supply reliable?	
	Size of MCB in home	
	Is there any voltage problem?	

APPENDIX V: Plagiarism Report

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ORIGINALITY REPORT

12%	8%	8%	10%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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APPENDIX VI: Research Paper

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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.

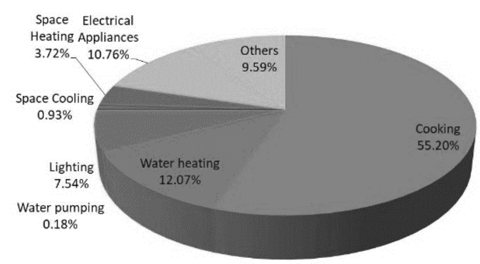

Figure 1: Energy share of different purpose - 2018

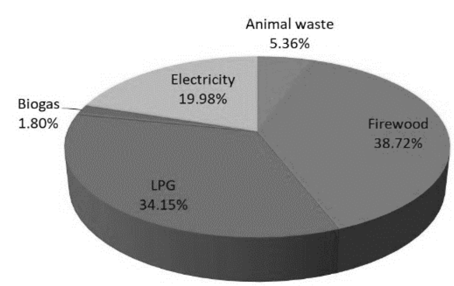

Figure 2: Energy share of different fuels - 2018

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.

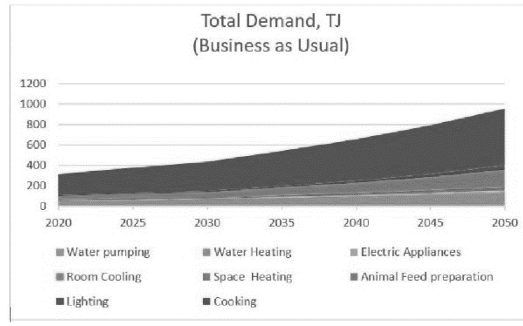

Figure 3: Demand for different subsectors - BAU

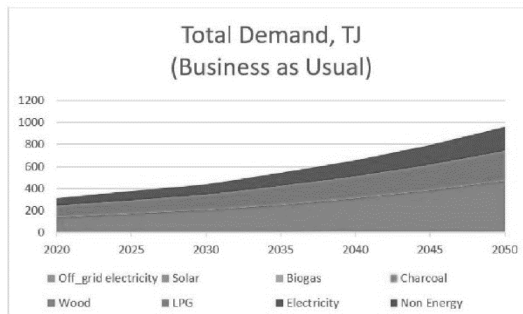

Figure 4: Demand for different fuels - BAU

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.

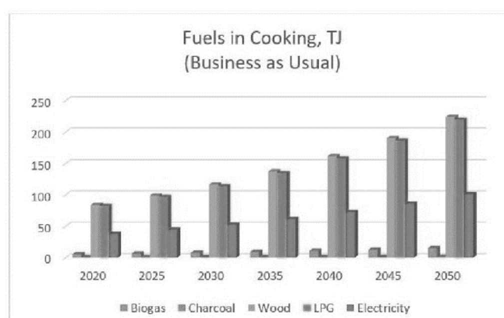

Figure 5: Fuels used in cooking - BAU

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.

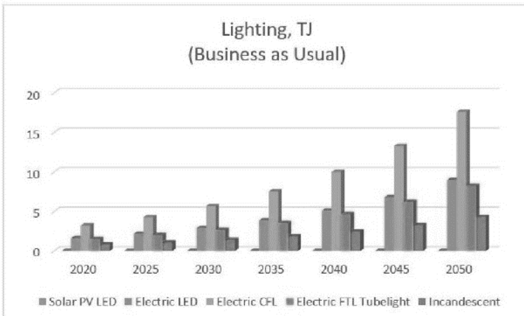

Figure 6: Lighting technologies - BAU

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.

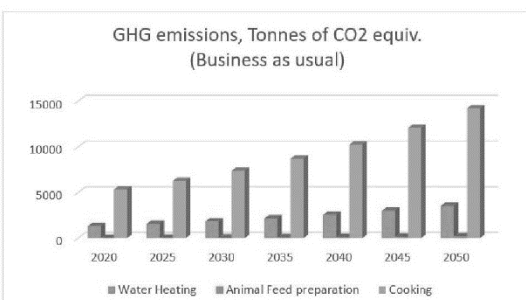

Figure 7: Subsectorwise GHG emissions - BAU

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

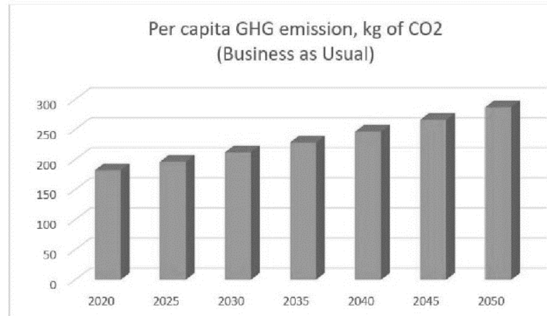

Figure 8: Per capita GHG emissions - BAU

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.

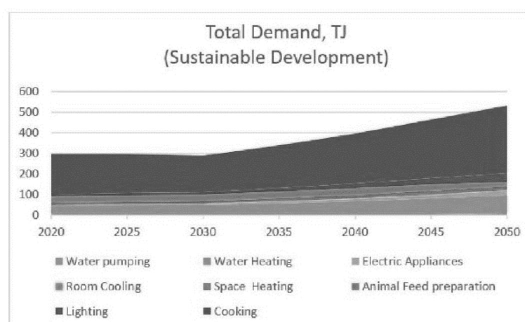

Figure 9: Demand for different subsectors - SUS

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

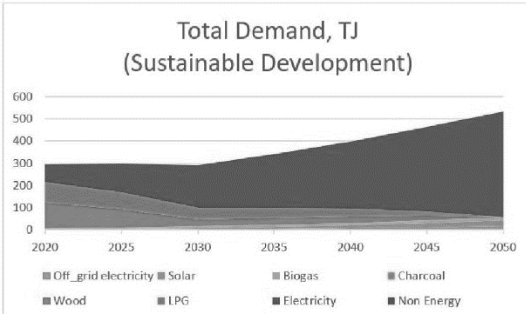

Figure 10: Demand for different fuels - SUS

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].

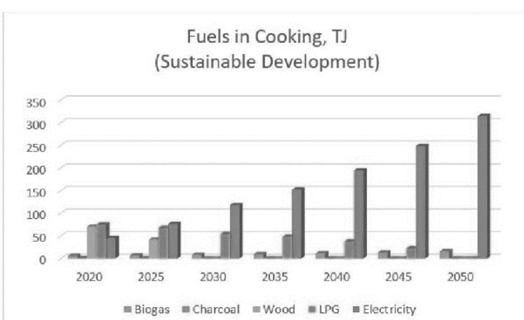

Figure 11: Fuels used in cooking - SUS

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.

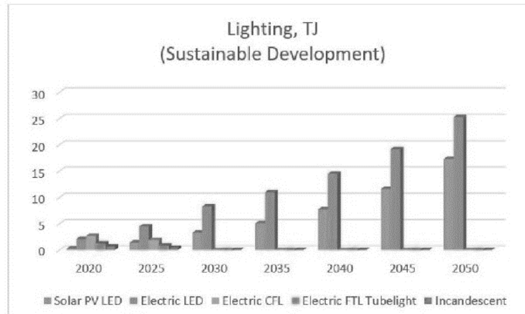

Figure 12: Lighting technologies - SUS

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.

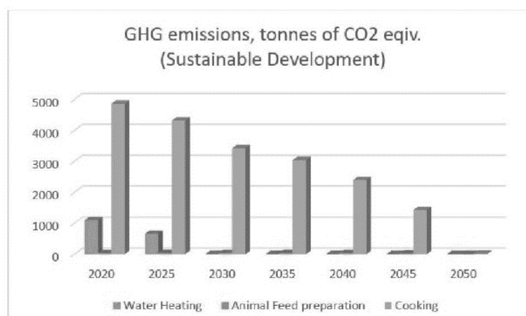

Figure 13: Subsectorwise GHG emissions - SUS

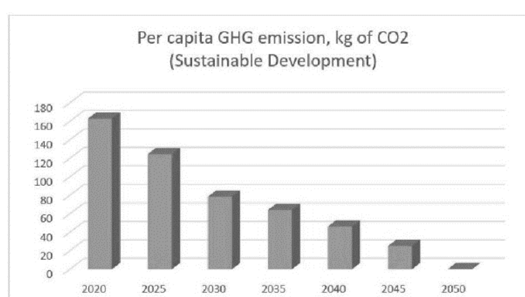

Figure 14: Per capita GHG emissions - SUS

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.

Acknowledgments

A special thanks go to the editors and the reviewers of the research paper for their comments and guidance to write this paper. Also, it cannot be forgotten to show gratitude to the lecturers and professors of the Department of Mechanical Engineering, Pulchowk Campus, for their valuable support during the study. Likely, an appreciation goes to the elected Mayor, Vice Mayor and other officials of Neelakantha Municipality for providing the available data for this study.

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