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SUSTAINABLE ENERGY PLANNING AND MODEL DESIGN WITH INCLUSION OF RENEWABLE ENERGY: A CASE OF RESIDENTIAL SECTOR AT KIRTIPUR MUNICIPALITY

By:

Jenish Maharjan

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in Partial fulfillment of the requirements for

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DEPARTMENT OF ARCHITECTURE

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CERTIFICATE

This is to certify that this thesis entitled ***"**Sustainable energy planning and model design of residential house with inclusion of renewable energy: A case of residential sector at Kirtipur municipality**"*** submitted by Jenish Maharjan has been examined and it has been declared successful for the fulfilment of the academic requirement of towards the completion of the Master of Science Course in Energy for Sustainable Social development.

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Prof. Dr. Amrit Man Nakarmi

(Thesis Supervisor)

Date:………………………………

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Jenish Maharjan (073/MSED/455)

ABSTRACT

Rapid urbanization has made Kathmandu Valley one of the fastest growing metropolitan cities in South Asia, resulting to higher energy demand. Kirtipur municipality has the highest population growth rate of 4.47% leading to higher energy demand in near future. The recent blockade has revealed the current energy security of Nepal. This research deals with the current energy consumption pattern and energy demand of Kirtipur municipality and Sustainable energy planning with inclusion of Renewable energy. A primary survey was conducted with the household questionnaire and the secondary data were collected from various resources. Data collected were further analyzed on Microsoft-Excel to find out the current energy consumption in the case area. And further analyzed on the Long- Range Energy Alternative Planning System with the energy model with bottom to top approach.

The total energy consumption of Kirtipur municipality was 261.5 TJ in 2018. Cooking was the most energy intensive end use and use of import fuel Liquefied Petroleum Gas has the higher demand. If none of the interventions are made in near future and the current energy consumption trend is continued the sustainable goal for multitier matrix cannot be meet by 2030 i.e. electricity consumption per household per year should be more than 3000Kwh. Two scenarios Electrification by Hydro Electricity (EHE) and Sustainable Development Goal (SDG) were developed with the fuel switching to clean energy and energy efficient technology i.e. Hydro Electricity, Solar electricity and Solar energy. The SDG scenario moreover focuses on the electricity generation from the Rooftop Solar PV resulting to 54% of Total Electricity demand can be substituted by the electricity generated through the rooftop solar PV. The self-generation of electricity from the Solar PV not only minimize the Grid Load but also provides the energy security and reduce Green House Gas emission. Electricity can be self-generated with the Solar roof Photovoltaics so for the further development of the Roof top Solar home system model design of Solar roof Photovoltaics has been done as per the building bye laws of Kirtipur municipality. The social use of the roof of the house has also been taken as the factors affecting for the model design of Roof top Solar PV. The policies should be driven by strategies for utilization of indigenous renewable resources instead of importing petroleum products. With the effective policy intervention, the energy demand and the emissions and the economic aspects can be minimized for the sustainable energy planning.

Keywords: energy demand, energy security, energy scenario, Renewable energy

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATION

ADB	Asian Development Bank
AEPC	Alternative Energy Promotion Centre
BAU	Business as Usual
CBS	Central Bureau of Statistics
CFL	Compact Fluorescent Lamp
CO2	Carbon Dioxide
EHE	Electrification by Hydroelectricity
GHG	Greenhouse Gases
GJ	Gigajoule
HH	Household
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
LEAP	Long Range Energy Alternatives Planning
LED	Light-emitting Diode
LPG	Liquefied Petroleum Gas
Mt	Metric Ton
MW	Megawatt
NEA	Nepal Electricity Authority
NRs	Nepalese Rupees
PV	Photovoltaic
TCS	Traditional Cooking Stove
TJ	Terajoules
WECS	Water and Energy Commission Secretariat

CHAPTER 1: INTRODUCTION

1.1. Background

Since 2007, for the first time in human history, more than half of the world's population has been living in cities. Although covering only about 2% of the earth's surface, cities are responsible for about 75% of the world's consumption of resources. Least developed countries are expected to have the highest average urban growth rate of 3.3% per annum between 2010 and 2050 (Madlener and Sunak 2011). Rapid urbanization has made Kathmandu Valley one of the fastest growing metropolitan cities in South Asia, resulting to the need of better facilities and infrastructure. Energy plays a vital role for fulfilling the needs of facilities and infrastructure. Energy is also recognized as essential for human kind which links economic growth, and environmental sustainability. Energy is the one of the important components for the socio-economic development of the country. Access to reliable and affordable energy services are fundamental to reduce energy poverty by the development of indigenous energy resources like hydropower. Unless the energy sector is geared up for the efficient and indigenous hydropower resources, sustainable energy development cannot be achieved. Nepal's energy resources are presently classified into three categories: traditional, commercial and alternative. Traditional energy resources include fuel wood from forests and tree resources, agricultural residues coming from agricultural crops and animal dung in the dry form. Energy resources coming under the commercial or business practices are grouped into commercial energy resources that particularly include the coal, grid electricity and petroleum products. Biogas, solar power, wind and micro level hydropower are categorized into the alternative energy resources in Nepal. (WECS 2010).

Kathmandu valley is the largest and most populous urban agglomerate of Nepal. The valley constitutes major portions of three districts viz. – Kathmandu, Lalitpur and Bhaktapur constituting 85%, 50% and 100% land area of each districts (Pant and Dangol 2009). The overall energy consumption of Nepal is largely dominated by the use of traditional energy such as fuel-wood, agricultural residues and animal waste. About 77% of total energy consumed in Nepal is supplied from traditional sources and fuel- wood alone shares 70% (WECS 2017)These fuels are mostly consumed in residential sector. Firewood is the primary fuel used for cooking food in most part of the country. Overall, 64% of households use firewood as their main source of cooking fuel. Other fuels used for cooking are: LPG (18%), cowdung/leaves (14%), and other fuels (4%). Type of stove used for cooking is related to the issue of indoor pollution and the quality of life. 62% of urban areas households use gas stove and 58% of rural areas households use mud stove for cooking (CBS 2011). Looking at scenario of Kathmandu valley 69% of energy is consumed for only cooking purpose in which LPG is highly in used which is 46% (Rajbhandari and Nakarmi 2014).

1.2. Problem Statement

Kirtipur municipality is a semi urban area which is an ancient city having traditional settlements. It is rapidly growing in the periphery of the traditional settlement by the population growth rate of 4.47%. The LPG is major source of energy for cooking as it is easily available. LPG fuel is considered as a modern source of energy. But for a country like Nepal, where all the fossil fuels such as LPG and petroleum fuels are imported from neighboring countries such type of energy shifting is not suitable in term of energy security. Fully depending on imported LPG for cooking will face the problem of LPG import disruption and also rise oil price. So, use of energy efficient technologies and fuel shifting to clean energy is important in order to reduce energy demand.

1.3 Need and Importance of Research

Residential sector is one of the major contributors in the energy consumption amongst all other sectors such as industries, commercial, transportation, etc. The total energy consumed by the residential sector in Nepal is 81.9% (WECS 2010). Kirtipur municipality with one of the highest population growth rates of 4.47% reveals the energy consumption is going to more on near future. The problem of energy crisis has continued recently in 2016 which also shows the condition of energy security of Nepal. Switching to renewable energy and self-relying on hydropower is the best option for energy security in Nepal. i.e. economically viable hydropower capacity is 42,000 MW in Nepal. Energy scenario and policy analysis is highly in need for the better energy management and energy security. Energy have the direct impact on the people, their economy, Environment and society. Therefore, for the further development of the country in the sustainable manner, the energy crisis should be considered from the beginning.

In context of Nepal most of the research and the energy analysis has been done only in national level and not in local level as the objective of this research. The energy analysis done in national level may not be similar to the context of local level. It cannot be generalized from the point of view of national level. The requirement and the demand of the local level may be different than that of the national level. Therefore, it will be more appropriate to do the energy analysis from local level rather than from national level. It will be more contextual to draw out the result from local level and then taken to national level rather than from national level to local level and then trying to solve the problem of local level. That is why such research and analysis should be done from local level as purpose of this report which will we more appropriate and useful in context of Nepal. The use of renewable energy is minimal whereas by the 2030 the use of renewable energy share must be higher to meet the SDG 7. The energy planning is important for the further planning with the inclusion of renewable energy and self-energy generation.32

1.4. Research Objective

1.4.1 Main Objectives

- The main objective of the study is to analyze different energy scenario of household sector in Kirtipur Municipality for sustainable energy development and energy security with implementation of decentralized solar home system.

1.4.2 Specific Objectives

To accomplish the main objectives of the study, following specific objectives were considered.

- To find out the different energy sources and consumption pattern for household sector in the case area and projection of energy consumption to the year 2050.
- To find the potential GHGs and local air pollutants emissions to formulate energy plan with scenarios as a basis for GHGs emission reduction.
- Development of modular design with implementation of renewable energy like Solar PV for self-energy generation to achieve energy security.
- To analyze different scenarios for sustainable energy development.

1.5 Study Limitation

- The energy consumption by the private vehicles will not consider in the study.
- Environmental impact in term of GHGs emissions from energy consumption by household sector will only be calculated..

CHAPTER 2: LITERATURE REVIEW

2.1. Energy

Energy is key to growth and sustainability. Energy is in the center of almost every global opportunity and challenge the world faces today. It is becoming a basic need, just like water, food, clothing, health care and education. Unfortunately, not everyone is enjoying the benefits of this all-important innovation as one in five people worldwide still lacks access to modern electricity while 3 billion, some of whom have electricity connection in their homes, still rely on animal waste, charcoal, coal and wood for heating and cooking.

Energy consumption has been directly related to the gross national product, which is a measure of the market value of the total national output of goods and services. World-wide, about 80% of all energy used is currently from fossil fuels. There is simply not enough non-fossil fuel available for this. In order to mitigate the problem, we have to use the available energy much more efficiently. But this won't be enough either: We will have to change our behavior to reduce our personal energy consumption. We must change our current life style and seriously strive for a sustainable living (Energypedia 2017). Large differences exist in terms of energy consumption between some of the most developed economies, largely due to the differences in attitudes towards implementing energy efficiency measures.

2.2. Energy Scenarios of Nepal

Energy sector in Nepal is recognized as primary key to nation’s development and future economic growth which will allow government to meet its development goals. Government of Nepal has committed in energy sector reform and promotion of private participation in the sector in addition to setting quantitative targets for electricity generation, transmission and distribution, rural electrification and promoting efficient use of electricity. The major renewable energy supplied in Nepal is electricity which contributes only 2% of the total energy demand. As Nepal is proceeding towards sustainable pace, the major challenges at present are to create an environment in which the Nepali people can experience the social and economic transformation.

No proven significant deposits of fossil fuel are available in Nepal and it relies to a large extent on traditional energy resources. Nepal has no known deposits of oil, gas, or coal except for some lignite deposits. Biomass, oil products, coal, hydro, and electricity are its main sources of primary energy. Among these, biomass, in the form of firewood, agricultural waste, and animal dung, has consistently dominated supply because of the lack of other alternative energy sources and the poor state of the economy, particularly in the rural areas. The largest available renewable energy resource is hydropower, with a theoretical potential of approximately 83,000 MW. While economically viable hydropower capacity in Nepal stands at 42,000 MW the current installed capacity is only approximately 1044.6 MW in 2017 whereas the demand for electricity is 1508.2 MW and the difference between demand and supply is 463.6 MW(MOF 2017). In addition to hydropower, Nepal also possesses other renewable resources with significant potential, including solar and wind. Nepal averages approximately 6.8 hours of sunshine per day over a potential area of 6,074 km2 it also has a wind power density in excess of 300 W/m2 (WECS 2010). Table 1 shows how energy supply and consumption in the various sectors have increased since 1990 to 2014 (ADB 2015).

Table 1: Energy supply and consumption trend, 1990-2014 (ktoe) (Source: ADB,2017)

Item	1990	1995	2000	2005	2010	2014
Total Primary Energy Supply	**5,789**	**6,712**	**8,108**	**9.132**	**10,211**	**11,690**
Coal	49	74	258	248	303	484
Oil products	244	501	713	724	983	1,359
Natural gas	0	0	0	0	0	0
Hydro	75	100	140	216	276	326
Biomass	5,425	6,039	6,988	7.928	8.592	9,403
Total Final Energy Consumption	**5,761**	**6,667**	**8,041**	**9,050**	**10,107**	**11,534**
Industry	106	161	379	388	449	665
Transport	111	203	270	275	637	858
Residential	5,465	6,170	7,199	8,128	8,718	9,624
Commercial and public services	43	60	97	165	171	219
Agriculture/Forestry	33	60	75	72	118	151
Non-energy use	4	7	11	20	10	8

ktoe = kilotons of oil equivalent.

As per 13th National Plan, Nepal targets to increase the access to electricity to 100% of population of Nepal by the year 2027. 90 % of total population of Nepal have access to electricity (Energypedia 2017). The cost increase in fossil fuel, depletion of fossil fuel, climate change and environment concern measure will lead to switch over of fuel to electricity. Due to modernization and clean energy measure, traditional fuel will also be switched to electricity.

As per this scenario, traditional fuels in the activities in the residential sector are assumed to get switched to electricity.

The following are the key elements of the energy sector vision 2050 based on the sub sectorial vision reports: Nepal's Energy Sector Vision 2050 (WECS 2013)

1. Hydro-power is the "lead" energy sector long term demand for energy of all sectors to meet the short as well as long term energy needs of the country
2. Complete cooking in electricity in urban households by 2030 onwards
3. Enhanced share of electricity in cooking in rural households and total penetration of ICS in cooking with solid biomass remaining in the rural households.
4. Total electrification in lighting from 2030 onwards.
5. Traditional fuelwood stoves in rural areas will be completely replaced by ICS by 2030

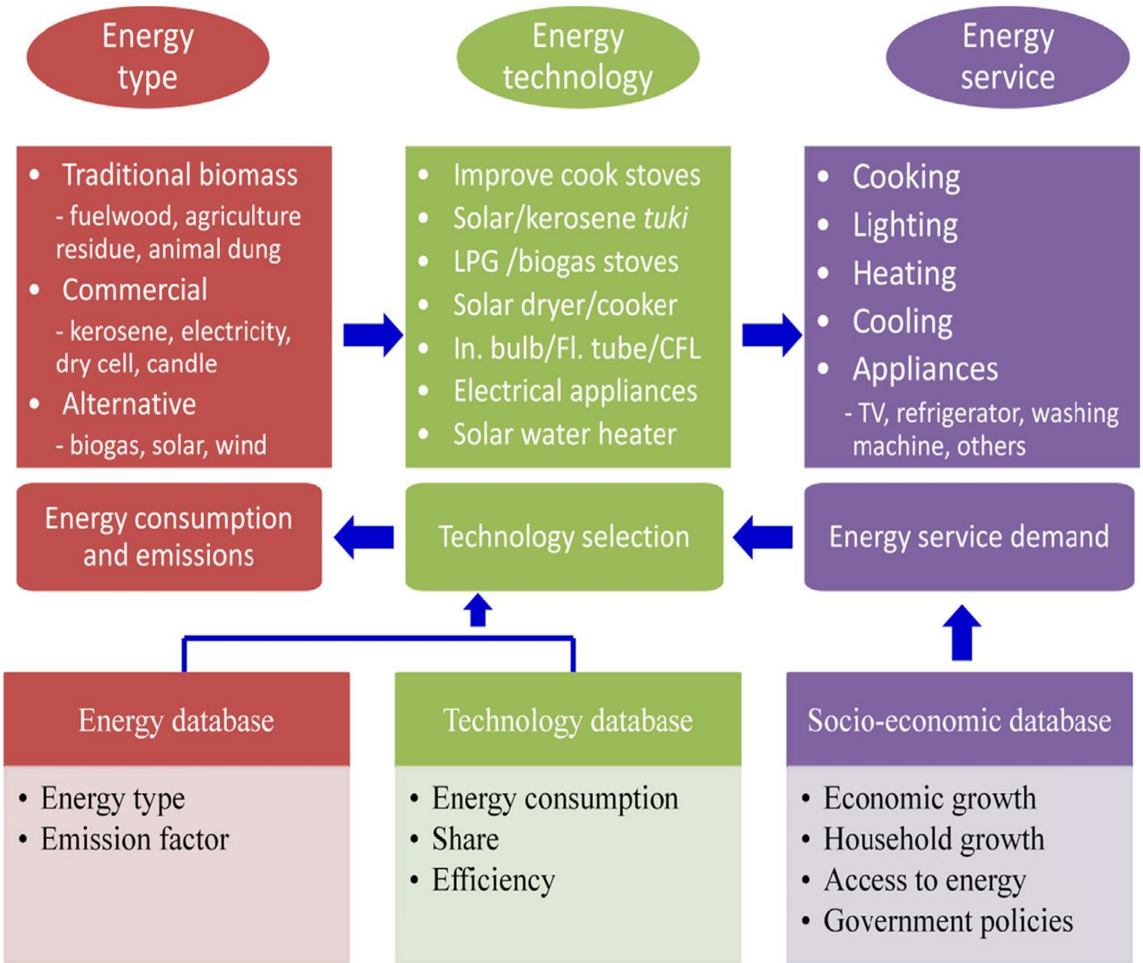

Figure 1 Structure of Nepal's household sector energy system modelling used in LEAP (Malla, 2013)

2.3. Energy Consumption in Nepal

Nepal has faced an increasing gulf between the demand and supply of energy in the past several years. More than a third of the population does not have access to electricity and is forced to depend on traditional fuels for energy requirements. Furthermore, Nepal’s electricity intensity is around 175KWh per capita, one of the lowest in the world. (Investment Board Nepal, 2018)

Energy Consumption Nepal's energy sources have been categorized under three broad types:

i. Traditional energy sources
ii. Commercial energy sources
iii. Alternative energy sources

Alternative energy is synonymous with new, renewable and non-conventional forms of energy. This categorization pertains to the modality of use of the resources in abstracting the inherent energy contents. Traditional source of energy includes biomass fuels particularly fuel wood, agricultural residues and animal dung used in the traditional way which is direct combustion, wherein traditional energy sources undergo transformations into modern types of fuels. Commercial sources of energy are fossil fuels and electricity. Alternative 4 sources of energy include micro hydro, solar, wind power, biogas and briquettes etc. Biomass, hydropower and Solar are the three major indigenous energy resource bases in the country. Though Nepal has a huge potential for hydropower production, its exploitation has been to a very minimal, and therefore, significant amount of energy supply comes from traditional energy sources such as biomass. Heavy dependence for energy on biomass resources has accelerated the depletion of natural resources and contributed to the degradation of natural environment. It is the biomass sector which dominates the overall energy supply and consumption in the country. (WECS, 2017)

2.3.1. Energy Consumption Pattern in Year 2014/2015

Table 2 and Figure 2 show the total supply and their share of energy consumption by various fuel types in Fiscal Year 2014/15. It reveals the share of fuel types in total energy demand system of the country. Total energy consumption in FY 2014/15 is 500 million Giga Joule (GJ); among which, fuel-wood is the largest energy resources and occupies about 70.47% of the total energy demand. Other sources of bio-masses are agricultural residues and animal dung which contribute about 3.48% and 3.68%, respectively. Share of petroleum fuels in the total energy system is about 12.53 %. Other sources of commercial energy are coal and electricity, which contribute about 3.97% and 3.39%, respectively in the total energy supply. In aggregate, the share of traditional fuel is 77.63%, Commercial (coal, petroleum and electricity) is 19.88 % and Renewable (Solar, Biogas, Micro hydro, Wind) is 2.49%. (WECS 2010)

Table 2 Distribution of Energy Consumption by fuel types in FY 2014/2015

S. No.	Fuel Types	Amount (000GJ)	Percentage share
1	Fuel Wood	352229.10	70.47
2	Agriculture-residue	17408.43	3.48
3	Animal dung	18401.96	3.68
4	Coal	19819.09	3.97
5	Petroleum	62618.27	12.53
6	Electricity	16932.75	3.39
7	Renewable	12430.26	2.49
	Total	499839.86	

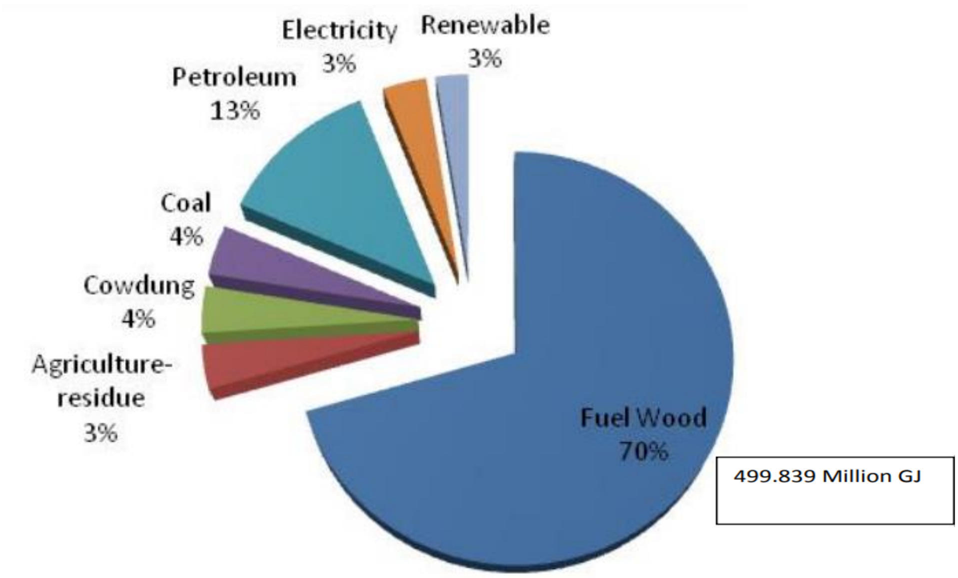

Figure 2 Share of Energy Consumption by Fuel-types in 2014/15

The electricity consumption and the number of consumers increase at a rate of approximately 9 % per year, according to the Nepal Electricity Authority (NEA). Because of increasing household consumption, the evening peak demand has risen dramatically. Due to the continuously rising demand and stagnation in creating additional power generation capacities, a noticeable shortage of power supply since 2007 has been the consequence, which forced the NEA in early 2009 to cut power for up to 20 hours per day in some regions including urban centers.

The NEA as the major electricity utility faces an immense increase in electricity demand, whereas at the same time production and transmission capacities are limited. Though, ambitious development targets are announced by politics, the development of plants and transmission lines cannot keep up with economic development and its induced demand increase.

Between 2005 and 2014 (estimated figures) peak demand has more than doubled from 557 to 1200 MW. In the same period of time annual electricity production increased from 2642 GWh to 4631 GWh. Out of these, 3558 GWh have been produced domestically, while 1072 GWh have been imported from India (Energypedia 2017).

2.4. Energy Scenario in Residential Sector

Figure 3 shows, the largest share of energy consumption goes to the residential sector. The share of industry and transport is now small, but these sectors are growing fast. Following figure presents the share of each sector in total final energy consumption in 2014 and the major energy sources and their percentage share of the total supply of primary energy in 2014.

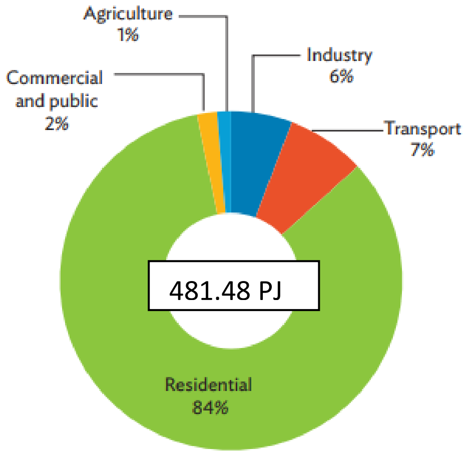

Figure 3: Final Energy consumption mix (ADB,2014)

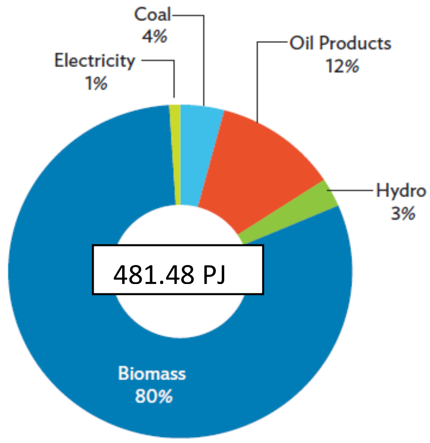

Figure 4: Primary energy supply mix (ADB,2014)

residential sector constituted almost 89 per cent of the total energy consumption in the country in 2008/09. Residential energy consumption is the amount of energy that is spent on the various appliances used within housing.

The residential buildings in the urban centers of Nepal mainly use electricity and LPG for lighting, heating and cooling purposes. The urban residential sector makes up about 14.5 per cent of the total residential sector energy consumption. About 52 per cent of the urban energy is used for cooking purposes followed by electric appliances (14 per cent), lighting (13 per cent), heating and cooling (10 per cent), animal feeding (8 percent) and agricultural processing (3 per cent). The overall growth rate of energy consumption in the residential sector is about 2.3 per cent per annum.

Agricultural residues are generally used in the rural residential sector both for igniting wood fuel and as the main energy source in areas where fuelwood is in short supply or scarce. Among the traditional fuels, fuelwood alone contributes to around 89 per cent in the total energy consumption for domestic cooking. Animal dung was mostly consumed in the residential sector. If we were to concentrate on reducing energy demand in the residential buildings in urban locations, even a nominal percentage reduction in energy use in buildings would have a significant impact on national energy requirements, and this could be achieved with little investment or simply by being more diligent in our use of energy in homes.

Because of the large gap between the supply and demand of electricity in our country, greater focus has been given on generating more electricity.

2.4.1. Household Energy Consumption in the Year 2014/2015

The energy consumption of different sectors was studied from different reports and these data were analyzed and energy consumption for the different sectors like Residential, Commercial, Industrial, Transport and others were estimated for the year 2014/15 (Shrestha & Nakarmi, 2015)

According to the Journal, “Demand Side Management for Electricity in Nepal: Need analysis using LEAP Modeling Framework”- (Shrestha & Nakarmi, 2015) Table-3 below illustrates that current scenario of sectoral energy consumption which is dominated by Residential sector as Nepal being developing country. Figure – 5 shows the Residential energy consumption is found to be around 80% followed by Industrial and Transport sector which contributed around

8% of total energy consumption. The commercial sector energy consumption is found to be 3.6% whereas agriculture and other energy combine consumption contributed to just over 1% of total energy consumption.

Table 3 Energy Consumption in the year 2014/15 (Shrestha & Nakarmi, 2015)

Economic Sector	Traditional Fuel, PJ	Commercial Fuel, PJ	Renew. Fuel, PJ
Residential	353	14	12
Industrial	9	30	0
Commercial	9	8	0
Transport	0	32	0
Agriculture	0	5	0
Others	0	1	0
Total	371	90	12

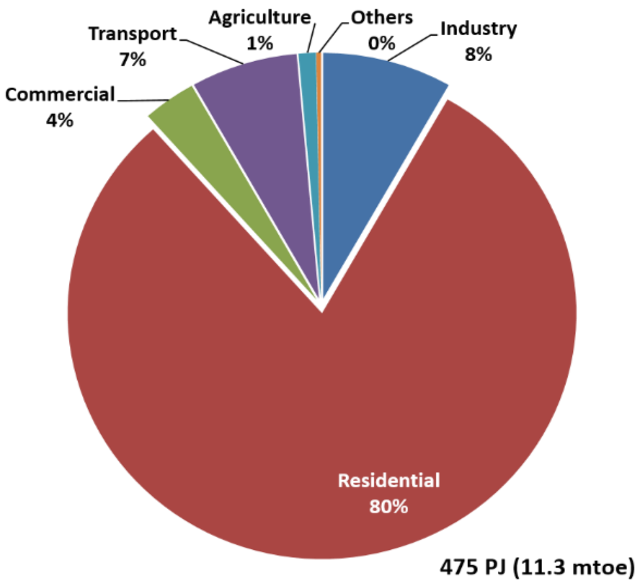

Figure 5 Sectoral Energy Consumption in 2015 (Shrestha & Nakarmi, 2015)

The traditional fuel, namely Fuel wood contributes to more than 85% of the total fuel share whereas the contribution by agricultural wastes and animal wastes is almost 8%. The petroleum combined contributes little over 2% whereas Electricity's contribution is 1.6% as shows in the Figure – 6. There is very low contribution of solar and micro hydro in residential sector. (Shrestha & Nakarmi, 2015)

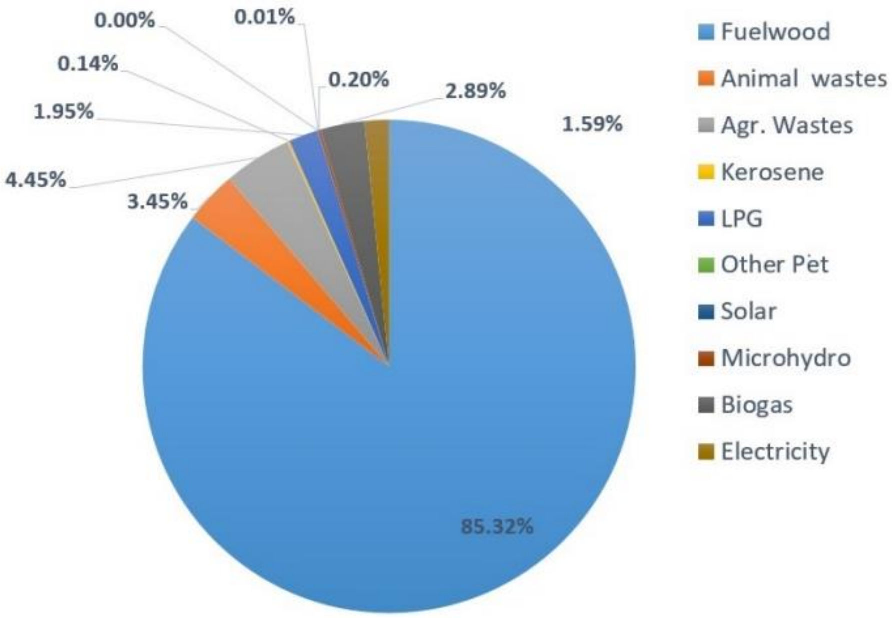

Figure 6: Fuel share in Residential Energy Consumption (Shrestha & Nakarmi, 2015)

Table -4 shows that Cooking, heating, water boiling has always been the most energy consuming end use in residential sector. It is due to fact that fuel wood is used as the major sources. In case of electricity consumption, its share is divided well showing the potential of electrical energy in all end use. (WECS 2012)

Table 4: Fuel share in Residential Energy Consumption (WECS, Energy Sector synopsis report, 2012)

In 000 GJ		
End Use	**Residential Total**	**Residential Electricity**
Cooking	184318.5	878.5
Heating	42872.1	174.2
Cooling	609.4	609.4
Lighting	2317.7	1159.3
Water Boiling	38924.5	326.5
Water pumping	364.9	363.6
Electrical Appliances	1173.6	1114.9
Other Uses	31804.1	197.4
Total	302384.8	4823.0

The cooking activity majorly consumes energy (61%) whereas space heating (14%) and water boiling (13%) are next two activities contributing highly in energy consumption. Lighting only consumes 0.72% of residential energy consumption. Electrical appliances contribute 0.41% residential energy consumption whereas water pumping contributes only 0.12% of residential energy consumption. The other activities share almost 10% of residential energy consumption as shown in the Figure 7. (Shrestha & Nakarmi, 2015

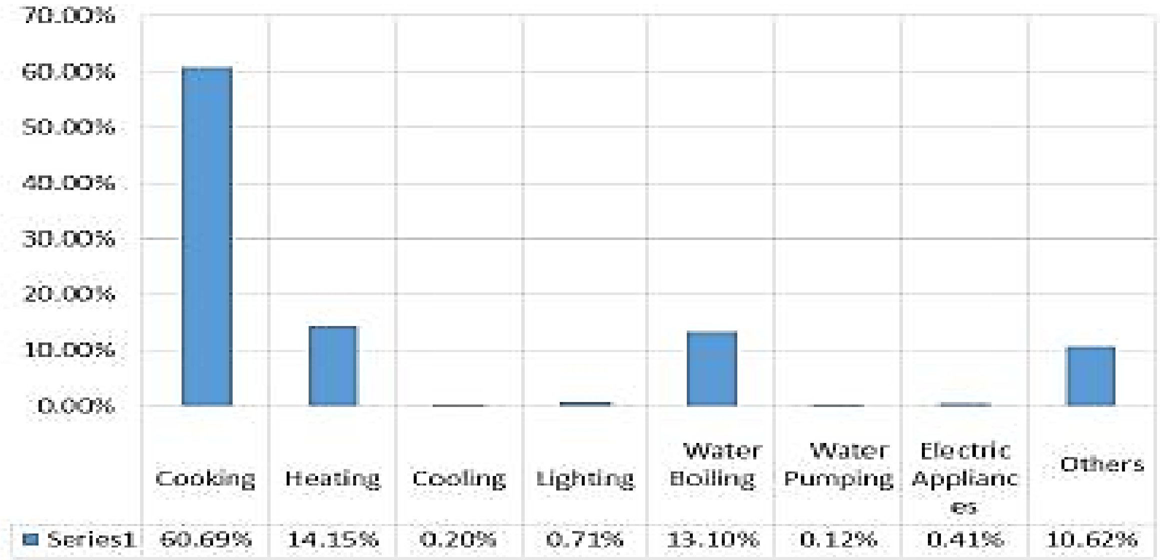

Figure 8: Activities in Residential Energy Consumption (Shrestha & Nakarmi, 2015)

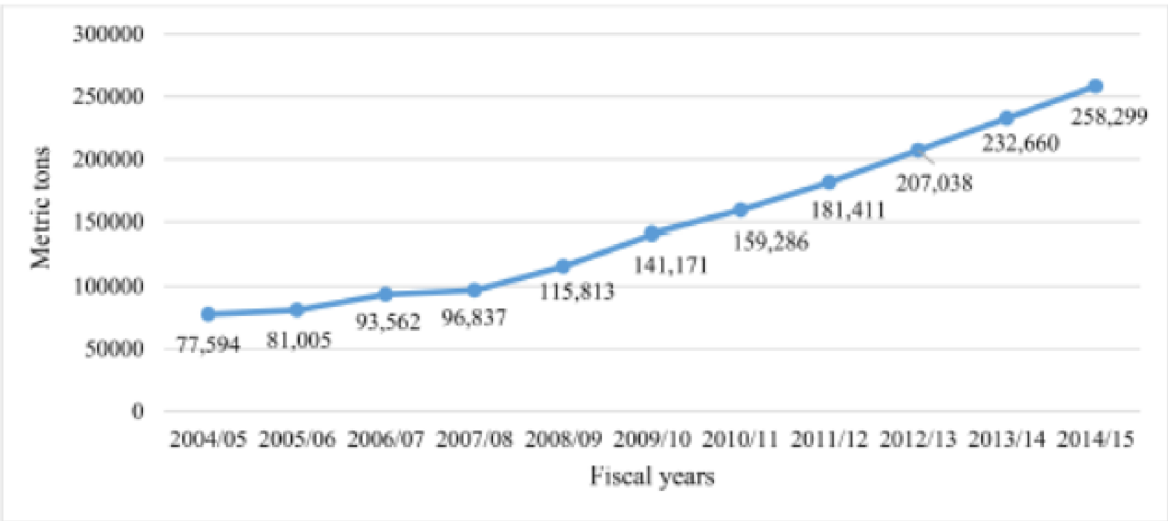

Figure 7: Historical trend of LPG consumption (Source: Bhandari and Pandit, 2018).

2.5 Household Fuel Choice and Fuel Transition

Household fuel choice is the subject of a lot of research and has generated a number of different theoretical models. Early thinking on this issue was based around the "energy ladder model" and the associated notation of fuel switching.

The model describes fuel transition from traditional fuels to modern fuels and suggests that with increasing income or economic status, a progression is expected from traditional biomass fuel to more advanced and less polluting fuels. Based on household income, a household energy choice undergoes a linear three-stage switching process (Leach 1992). This process starts with solid fuel biomass fuels and, with increasing economic prosperity this leads to a transition phase involving kerosene, coal and charcoal. It finishes with LPG and electricity (Mishra 2008).

Household fuel switching is not a linear or unidirectional process, and economic factors are not the only variables that determine fuel choice. Access and consistent availability are also important: for example, households that are willing and able to pay, simply will not make the switch from charcoal to LPG if the gas, stove, and gas bottles are not consistently available in a convenient location. The income is not the only determinant of transition from traditional to more convenient forms of energy, other factors such as access to alternative energy sources and consumer preferences also account for a household energy choice. According to (Masera, Saatkamp et al. 2000), the different fuels and stoves carry a social status as well. Hence, the greater costs of advanced technologies are on one hand compensated by the greater fuel efficiency and cleanliness of the stove but also by the strived increase in societal status.

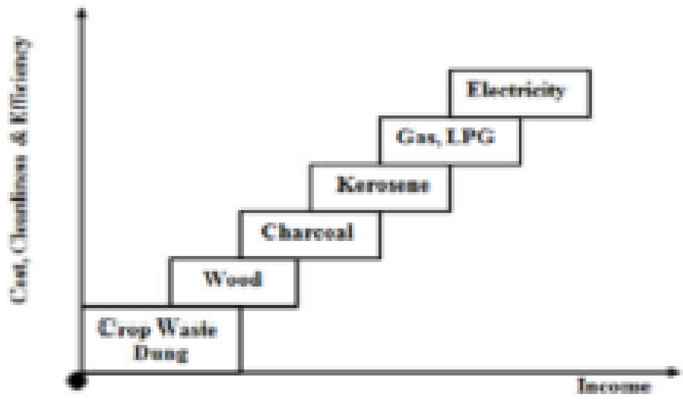

Figure 9: The Energy Ladder Approach (Source: Masera, et al., 2000)

2.6 GHG Emission

Residential sector is the major energy consuming sector which is about 80% of total national energy consumption of which 88% is traditional fuel (basically biomass). The use of cooking stoves or energy conversion technology practice in Nepal is generally open cooking stoves having efficiency of around 5%-7%. This implies that lots of energy is lost in the surroundings and at the same time emitting higher amounts of pollutants creating indoor air pollution. The figure shows that transport sector is the major carbon emission sector which accounts about 49% then emission in the year 2008/2009. followed by industry sector 25% and residential sector by 12% of total carbon emission in the year 2008/2009.

2.7 Solar Photovoltaic System

A Solar Photovoltaic (PV) System is a system which captures the sun's energy and converts it into useful energy i.e. electricity. It is a system composed of one or more solar panels combined with an inverter and other electrical and mechanical hardware that use energy from the Sun to generate electricity. PV systems can vary greatly in size from small rooftop or portable systems to massive utility-scale generation plants. Although PV systems can operate by themselves as off-grid PV systems, this article focuses on systems connected to the utility grid, or grid-tied PV systems.

Light hits the solar panels with photons (particles of sunlight). The solar panel converts those photons into electrons, direct current. Electrons then flow through a conductor to the various device. The material responsible for doing this conversion is call a cell. PV Solar system typically consists of four basic components. They are:

1. **PV Array:** Solar panels generate free power from the sun by converting sunlight to electricity with no moving parts, zero emissions, and no maintenance. The solar panel, the first component of an electric solar energy system, is a collection of individual silicon cells that generate electricity from sunlight. The photons produce an electrical current as they strike the surface of the thin silicon wafer. The most efficient and expensive solar panels are made with Mono-crystalline cells. These solar cells use very pure silicon and involve a complicated crystal growth process. Polycrystalline cells are a little less expensive and slightly less efficient than Monocrystalline cells because the

cells are not grown in single crystals but in a large block of many crystals (Gwamuri and Mhlanga 2012)

2. **Batteries:** Batteries are rated by the amount of current they can supply over a period of hours i.e. in ampere hours (Ah). The design should ensure enough Ampere-hour capacity to take account of any bad weather periods. An additional one-fifth capacity is thought to be sufficient to cover this eventuality.
3. **Inverter:** An inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power. The power is provided by the DC source.
4. **Charge Controller:** Charge controllers are used to control the charging of the batteries. Since the output from solar panels are variable and needs adjustments, charge controllers fetch the variable voltage/current from solar panels, condition it to suit the safety of the batteries. The main functions of charge controllers are to prevent over-charging of batteries from solar panels, over-discharging of batteries to the load and to control the functionalities of the load. (AEPC 2017)

Factors affecting Solar Panels are as follows:

- Temperature
- Shading
- Dust

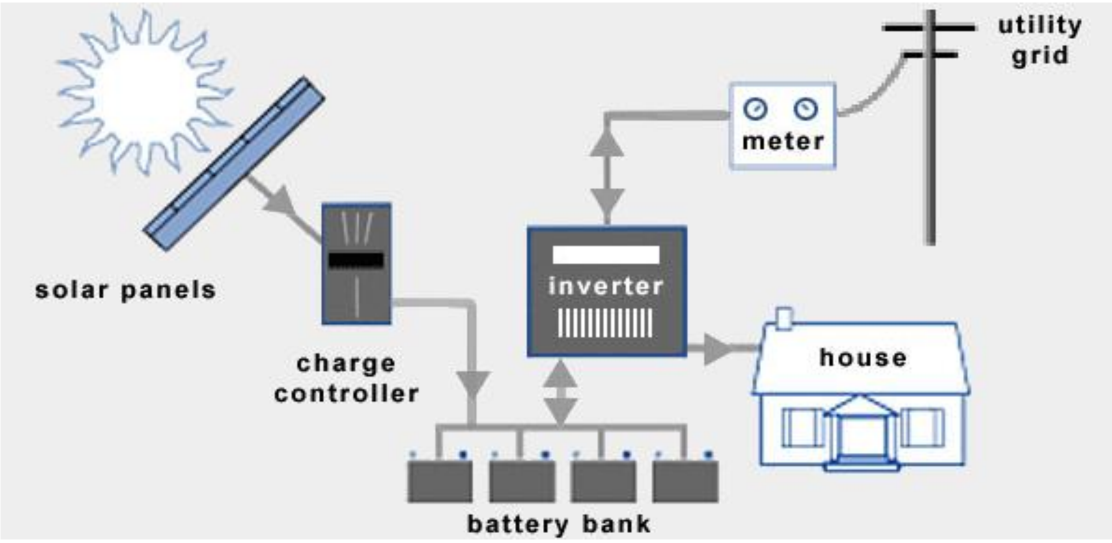

Figure 10: Solar Photovoltaic (PV) System

People in the urban context will shift from grid electricity use to stand alone solar PV system installation, only if it is economical to do so. Is there any possibility of economic feasibility and adaptation of solar PV systems in urban areas? This question can be answered with the help of benefit cost analysis (Bhandari and Stadler 2011). The solar PV system basically consists of two components module and balance of system (BOS). The BOS components include batteries and inverters, as well as other accessories, e.g. charge controllers, cables, electronic components, system installation and management, etc.

Overall PV system costs are projected to continue to decline rapidly, although uncertainties exist at the moment regarding the markets growth in the short term. Short-term projections for the PV market are rapidly out of date given the rapid pace of developments. Longer term projections are likely to experience less volatility. PV system costs for residential systems are projected to decline from USD 4 200 to USD 6 000/kW in 2010 to between USD 1 800 to USD 2 700/kW by 2020 and to USD 1 500 to USD 1 800/kW by 2030 (Table). (IRENA 2012)

Table 5 Installed PV system cost projections for residential and utility scale system, 2010 to 2030

	2010	2015	2020	2030
Utility-scale				
EPIA (c-Si)	3 600		1 800	1 060 - 1 380
IEA (c-Si)	4 000*		1 800	1 200
Residential/Commercial				
IEA	5 000 - 6 000*		2 250 - 2 700	1 500 - 1 800
Solarbuzz (c-Si)	4 560	2 280 - 2 770		
Solarbuzz (thin film)	4 160	1 860 - 2 240		

2.8 Hydropower in context of Nepal

As Nepal has good potential to establish hydropower plants because of its terrain and hydrology, its electricity generation is dominated by clean hydropower. Other electricity sources such as thermal power contributes less than 0.5% of total energy needs. However, as rivers are snow-fed, water level in river changes with season and so do the electricity generation. This is the main reason behind the long power cut enforced by NEA particularly in dry season. The NEA imported more than 14% electricity from India in 2012/13 to meet the shortfall but almost 22% of the demand was unserved. (Gautam, Li et al. 2015) With the growing rate of migration from rural to urban areas and increasing industrialization and business activities, the use of electricity in the residential sector has sharply increased. Most of the people with higher socio- economic strata are equipped with relatively modern electrical appliances and they reside in urban areas. This fact explains the rapid increase in the total residential energy consumption in urban areas compared to rural area (WECS 2010). NEA has predicted that annual electricity demand will continue to increase by 7-8% in coming decades. It has been predicted that the power demand will increase by three times reaching 3679.10 MW and the energy demand will reach 17403 GWh by 2027/28 (Gautam, Li et al. 2015) It will be a big challenge for the government and the utility companies to meet growing energy need.

Nepal is blessed with significant hydropower resources. Nepal's theoretical hydropower potential has been estimated to be around 84,000 MW, of which 43,000 MW has been identified as economically viable whereas the Currently, Nepal's installed hydropower capacity is 753 MW. As shown in the Table-8 and Table-9 Which is only the 2% of economically viable hydropower capacity of Nepal. (WECS 2010)

Table 6: Economic Hydropower Potential Source: WECS. 2010)

River Basin	Number of Project Sites	Economic Potential Capacity in MW
Sapta Koshi	40	10,860
Sapta Gandaki	12	5,270
Karnali	7	24,000
Mahakali	2	1,125
Southern Rivers	5	878
Country Total	66	42,133

Table 7: Theoretical Hydropower of Nepal (Source: WECS, 2010)

River Basin	Potential in MW		Total Potential in MW
	Major river courses having catchments areas above 1000 km^2	Small river courses having catchments areas 300-1000 km^2	
Sapta Koshi	18,750	3,600	22,350
Sapta Gandaki	17,950	2,700	20,650
Karnali and Mahakali	32,680	3,500	36,180
Southern Rivers	3,070	1040	4,110
Country Total	72,450	10,840	83,290

2.9. Sustainable Development Goals SDG

Sustainable development continues to be in-built in Nepal's socio-economic development. Nepal's efforts for the successful implementation of the MDGs have also opened new avenues for the implementation of SDGs planned for 2016-2030. Even before SDGs were endorsed and adopted by the UNGA in September 2015, the Government of Nepal was already in the process of preparing a National Report. This document is the final outcome of this preparation process. The Report assesses the national situation by each SDG from national perspectives, examines their relevance in the national context and provides inputs for national planning, dialogue, and shows a pathway for implementation.

The concept and measurement of energy access has gained significant interests from governments and development agencies. The Sustainable Energy for All (SE4All) initiative launched by the Secretary General of the United Nations in 2011 aims to achieve universal access to modern energy services by 2030. There are 17 proposed SDGs among which SDG 7 aspires to access to affordable, reliable, sustainable and modern energy for all by 2030. Nepal agrees with the Safe Energy for All (SE4ALL) document that the focus for energy access needs to better capture the quantity and quality of electricity supplied, as well as the efficiency, safety and convenience of household energy. Nepal has a huge potential for renewable energy, particularly hydropower. The SDG 7 targets include achieving the following by 2030:

i. Universal access to affordable, reliable and modern energy services.
ii. Substantially increasing the share of renewable energy in the global energy mix.
iii. Doubling the global rate of improvement in energy efficiency.
iv. Accessibility of 99 percent of households to electricity.
v. Reduce to 10 percent of households who use firewood as their primary fuel for cooking.

2.10. Tier Classification for Global SDG Indicators

Table 8: SDG 7: Targets with proposed indicators, current status and future projections

Targets with proposed indicators, current status and future projections						
Targets and Indicators	**2014**	**2017**	**2020**	**2022**	**2025**	**2030**
Target 7.1 By 2030, ensure universal access to affordable, reliable and modern energy services						
7.1a Per capita energy (final) consumption (in GL)	16[a]	17.5	19	20	21.5	24
7.1b Households using solid fuels as the primary source of energy for cooking (%)	74.7[b]	62.6	50.4	42.4	30.2	10
7.1c Proportion of people using liquid petroleum gas (LPG) for cooking and heating (%)	28.7[c]	30.8	32.9	34.4	36.5	40
7.1d Proportion of population with access to electricity (%)	74[d]	78.69	83.38	86.5	91.19	99
7.1.e Electricity consumption (kWh per capita)	80[e]	183.1	286.3	355	458.1	630

Energy Sector Management Assessment Program ESMAP, under the Sustainable Energy for All SE4ALL initiative, in consultation with multiple development partners has developed the Multi-tier Framework (MTF) to monitor and evaluate energy access by following a multi-dimensional approach. Access to electricity is measured based on technology-neutral multi-tiered standards where successive thresholds for supply attributes allow increased use of electricity appliances. A separate multi-tier framework can be defined for access to electricity services. A third multi-tier framework is defined for electricity consumption. Energy access is measured in the tiered-spectrum, from Tier 0 (no access) to Tier 5 (the highest level of access).

Table 9: Multi-tier matrix for electricity consumption (World Bank, 2015)

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Annual consumption levels, in kilowatt-hours (kWh)	<4.5	≥4.5	≥73	≥365	≥1,250	≥3,000
Daily consumption levels, in watt-hours (Wh)	<12	≥12	≥200	≥1,000	≥3,425	≥8,219

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Research Paradigm

3.1.1 Ontology : Ontology means the nature of the reality. The ontology of the study will be the current energy scenario of residential sector of kirtipur municipality

3.1.2 Epistemology

Epistemology means the nature of the Knowledge and what constitutes good knowledge. The Epistemology position of the research area has been found by the literature review, information's and data collected from different external sources, the local residents, and other involved organizations.

3.1.3 Methodology

In this research, Quantitative Approach has been applied for collection and analysis of data related to household energy consumption. This study consists the analysis of energy demand from the primary data collection. The research was carried out as per the flow chart given in Figure -11

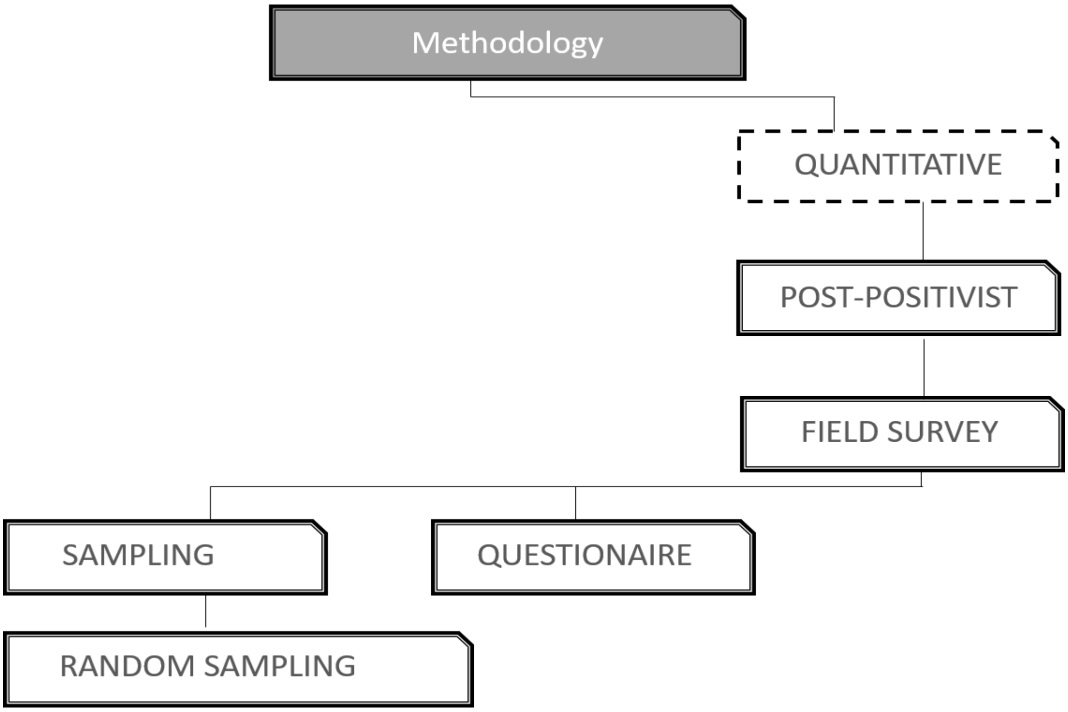

Figure 11Graphical representation of Research Methodology

3.2 Research Design

3.2.1 Study Area: Kirtipur

Kirtipur is a relatively small municipality in Kathmandu district of Bagmati Zone of province 3. The municipality lies 5 Km south west of Kathmandu. Kirtipur is bordered with Lalitpur metropolitan city on the east, Kathmandu Metropolitan city on the North, Dakshinkali Municipality on the South and Chandragiri Municipality on the south which is shown in Figure 12.

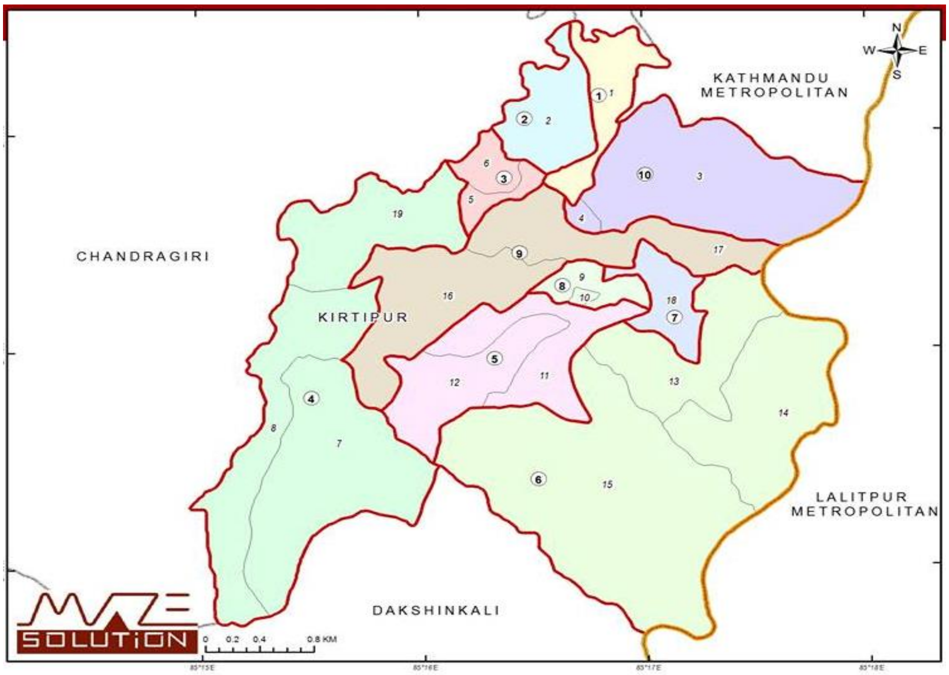

Figure 12 Map of Kirtipur Municipality

The total population in Kirtipur municipality in the year 2011 was 65,602 with population density 4445 per sq. Km. The total number of households was 19441 with household size 3.4 as shown in table 10.

Table 10: Data of Kirtipur Municipality

No. of Wards	10
Total area	14.76 sq.km
Population (2011)	65,602
No. of household (2011)	19441
Growth rate	4.47%
Household size	3.4
Population Density	4445 per sq km

3.2.2 Sample Size and Field Determination

As per the Central Bureau of Statistics-2011, There are about 65,602 population in Kirtipur Municipality. It is more time consuming to collect the energy consumption data from all the households. So, suitable sample size was taken to determine the total energy consumption for the analysis.

There are various formulas for calculating the required sample size based on the data collected is to be of a categorical or quantitative nature. The sample size was calculated using the following formula (Krejcie and Morgan 1970)

$$S = \frac{x2NP(1-P)}{\{e2(n-1)+x2P(1-P)\}}$$

Where,

S = Required sample size

x2= Table value of chi-square for 1 degree of freedom at the desired confidence level

N = population size

P = population proportion

e = Error Percentage

It consists of 10 wards and about 65602. With the confidence level of 95% and the degree of accuracy (e) 8%, the sample size would be 155 households. After the determination of sample size i.e. 155 households, the number of households were determined on the basis of proportion of household distribution in each ward. So that data collection would cover households from all wards of Kirtipur Municipality. The number of samples from each ward is shown in Table 11.

Table 11 sample size distribution according to wards

Ward No.	Sabik ward	Households	Males	Females	Total Population	Area/ha	Sample percentage	Sample size
1	1	1915	3674	3034	6708	43.11	0.10	15
2	2	1863	3610	3118	6728	71.89	0.10	15
3	5,6	1414	2738	2382	5120	50.27	0.07	11
4	7,8,19	1426	3079	3079	6161	640.42	0.07	11
5	11,12	2027	3821	2937	6758	158.64	0.10	16
6	13,14,15	1678	3586	3696	7282	464.85	0.09	13
7	18	1722	2934	1727	4661	34.52	0.09	14
8	9,10	1359	2447	1759	4206	17.19	0.07	11
9	16,17	2845	4911	3331	8242	143.78	0.15	23
10	3,4	3192	5676	4063	9736	176.68	0.16	25
Total		19441	36476	29126	65602	1801.35	1.00	155.0

3.2.3 Questionnaire Development

Questionnaires are typically used to collect primary data and to determine the current status or to estimate the distribution of characteristics in a population. Questionnaire was developed to collect primary data on the final household energy consumption of Kirtipur Municipality. Questionnaire was prepared on the basis of the energy consumption by fuel types such as firewood, LPG, kerosene, electricity, solar, agricultural residue etc. and energy consumption by end use such as cooking, lighting, water heating room heating/ cooling and other electric appliances. The primary data was collected in the hardcopy of questionnaire. The collected data was used as input in the LEAP software. The sample of questionnaire is shown in Appendix-1.

3.2.4 Field Survey

After finding the sample size requirement on each ward, the prepared questionnaire was taken and collection of energy consumption data was done. First, a pilot test was done with small sample to identify question in the questionnaire seem to be unclear to the participant or not. During the pilot survey, it was found that people felt difficulty in some of the questions. Accepting this flaw final questionnaire was prepared by rectifying flaws seen in the pre- questionnaire. After that total 155 energy related data were gathered through questionnaire survey.

3.2.5 Data Collection

The data were collected from the questionnaire prepared for the further energy demand calculation and further energy planning. The data collected were of two type primary data and secondary data.

Primary Data Collection

Primary data collection is the main part of the study. The household survey was conducted through quantitative method. The primary data collections were divided into two sectors which were energy consumption data of houses of traditional settlement and newly developed settlement. The collected data includes the energy consumption of households by end-use such as cooking, lighting, room heating, cooling etc. and by fuel type such as LPG, agricultural residue, electricity etc.

Secondary Data Collection

The primary data collection from households was not enough for analyzing in LEAP secondary data was also needed. Secondary data such as efficiencies, load dispatch data, population and GDP elasticities were collected from various publications including project reports, books, journal, NGOs, INGOs and electronic materials were collected for this study the total number of households, population, population growth rate were collected from CBS report.

3.2.6 Data Compilation

The collected data were in the questionnaire sheet, which was time consuming to find the actual situation of energy consumption. So, the collected household energy data were compiled in Microsoft Excel for the energy demand calculation of Kirtipur municipality of 2018.

3.2.7 LEAP - Leap Long-Range Energy Alternatives Planning System Energy Model

The Long-range Energy Alternatives Planning system (LEAP) is a scenario-based energy environment modeling tool. Its scenarios are based on comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions on population, economic development, technology, price and so on. With its flexible data structures, LEAP allows for analysis as rich in technological specification and end-use detail as the user chooses.

LEAP is used for the further energy analysis of the data's complied using MS- Execl and the policy intervention scenario development of other sustainable energy planning with the implementation of renewable energy ash shown in the Figure 13. Leap serves several purposes: as a database, it provides a comprehensive system for maintaining energy information; as a forecasting tool, it enables the user to make projections of energy supply and demand over a long-term planning horizon; as a policy analysis tool, it simulates and assesses the effects - physical, economic, and environmental - of alternative energy programs, investments, and actions. energy initiatives, and arrive at strategies that best address environmental and energy problems.

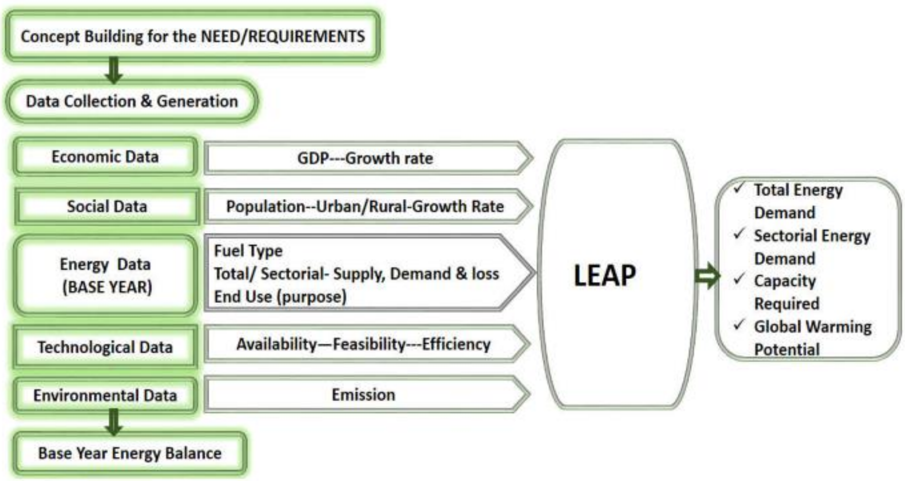

Figure 13: Leap Modeling Framework

3.2.8 Energy Demand

For modelling energy demand in leap, household sector was sub-categorized into seven end-uses:

a. Cooking
b. Lighting
c. Electrical Appliances
d. Water Heating
e. Space Heating
f. Space Cooling
g. Others

Further the end use categories were divided on the basis of fuel types. As the population increase, the energy demand will also increase. The energy demand is the product of energy intensity and demographic factor. The energy intensities of households for the base were calculated from primary data and net heating values of fuel. Then the required data: energy intensities and efficiency of technologies were entered in a leap model.

$$\textbf{Energy demand} = \textbf{energy intensity} \times \textbf{Population}$$

3.3 Scenario Development

Scenario planning is a foresight methodology which helps make sense of an uncertain future. It has been widely and effectively employed in many arenas to look at a possible range of actions and the resultant impact on policies, designs, and Flexible long-term plan. The purpose of scenario development is to anticipate future possibilities in such a way as to develop the most robust plans, designs, and policies leading to sustainable solution.

3.3.1 Business as usual scenario (BAU)

Business as usual scenario is the base line scenario which assumes that the past trends will continue in the near future year and no additional measurement will be put into practice. Thus, the share of each demand technology in the energy supply in future years will be same as in the base year. In this scenario, population growth rate will be same as base year.

3.3.2 Electrification by Hydro Electricity Scenario (EHE)

Electrification by Hydro Electricity Scenario follows the principle objectives of sustainable energy for all (SE4ALL) that promote access of electricity for all. In this scenario, there will be access of uninterrupted electricity supply policy. This scenario promotes the potential of electricity generation from hydropower and solar PV. The inefficient fuel as well as fossil fuel will gradually replace by electricity and solar. The end-use inefficient technologies will gradually replace by the energy efficient technologies such as LED is penetrated replacing incandescent bulbs and fluorescent tube lights. The population growth will be same as Business-as-Usual scenario. The fuel and technology switching in the EHE scenario is shown in the Table 12.

Table 12 Electrification by Hydro Electricity Scenario (EHE)

End Use Activity	Fuel Switching		Technology Switching	
	Existing	EHE Scenario	Existing	EHE Scenario
Cooking	LPG and Electricity	Hydro Electricity	LPG stove, Rice Cooker and Induction cooker	Induction cooker
Lighting	Hydro electricity , Solar Electricity	Hydro Electricity	Incandescent Bulb, Fluroscent LIGht, CFL and LED	LED
Electrical Appliances	-	-	-	-
Water Heating	Hydro Electricity, LPG, Solar Thermal	Solar Thermal	Gas Gaser, Electric Heater	Solar Thermal water heater
Space Heating	Hydro electricity and LPG	Hydro Electricity	LPG Heater , Electric Heater	Electric Heater
Space cooling	Hydro Electricity	Hydro Electricity	-	-
Others	Biomass (Agri-Residue, Firewood)	Biomass (Agri- Residue, Firewood)	-	-

3.3.3 Sustainable Development Scenario (SDG)

Sustainable Development scenario also follows the principle objectives of sustainable energy for all that promoted electricity and solar energy for sustainable development. Traditional and fossil fuels will gradually replace by clean fuels: electricity and solar in order to reduce GHGs and local air pollutants emission. In this scenario the total Energy Consumption is targeted to more 3,000KWh per household. The population growth will be same as in BAU scenario. The fuel and technology switching in the SDG scenario is shown in the Table 13.

Table 13 Sustainable Development Scenario (SDG)

End Use Activity	Fuel Switching		Technology Switching	
	Existing	SDG Scenario	Existing	SDG Scenario
Cooking	LPG and Electricity	Hydro Electricity	LPG stove, Rice Cooker and Induction cooker	Induction cooker
Lighting	Hydro electricity , Solar Electricity	Solar Electricity	Incandescent Bulb, Fluroscent LIGht, CFL and LED	LED
Electrical Appliances	Hydro electricity	85 % to Solar Electricity, 15% to Hydro Electricity	-	-
Water Heating	Hydro Electricity, LPG, Solar Thermal	Solar Thermal	Gas Gaser, Electric Heater	Solar Thermal water heater
Space Heating	Hydro electricity and LPG	Hydro Electricity	LPG Heater , Electric Heater	Electric Heater
Space cooling	Hydro Electricity	Hydro Electricity	-	-
Others	Biomass (Agri-Residue, Firewood)	Biomass (Agri- Residue, Firewood)	-	-

CHAPTER 4: FINDING AND DATA ANALYSIS

4.1 Energy Scenario in the Base Year 2018

The energy demand and consumption pattern of the Kirtipur municipality in the base year 2018 is different in different house types. The energy scenario in the year 2018 incudes the final energy demand by end use and fuel types and electricity consumption in different types of houses in Kirtipur municipality.

4.1.1 Per Capita Energy Consumption

The energy consumption of Kathmandu valley is 3 GJ per capita in 2014 (Rajbhandari and Nakarmi 2014). A figure shows that the per capita energy consumption of Kirtipur municipality is 3.14GJ which shows that the per capita consumption energy is similar to the study of Kathmandu valley which was done in the 2014. From this figure it can be seen that the energy consumption in the houses of traditional settlement is quite less than the energy consumption in the houses of newly development settlement which are 2.73 GJ and 3.24 GJ respectively. These difference in energy consumption is due to the living style, use of appliances of the people in the traditional settlement and the newly development settlement.

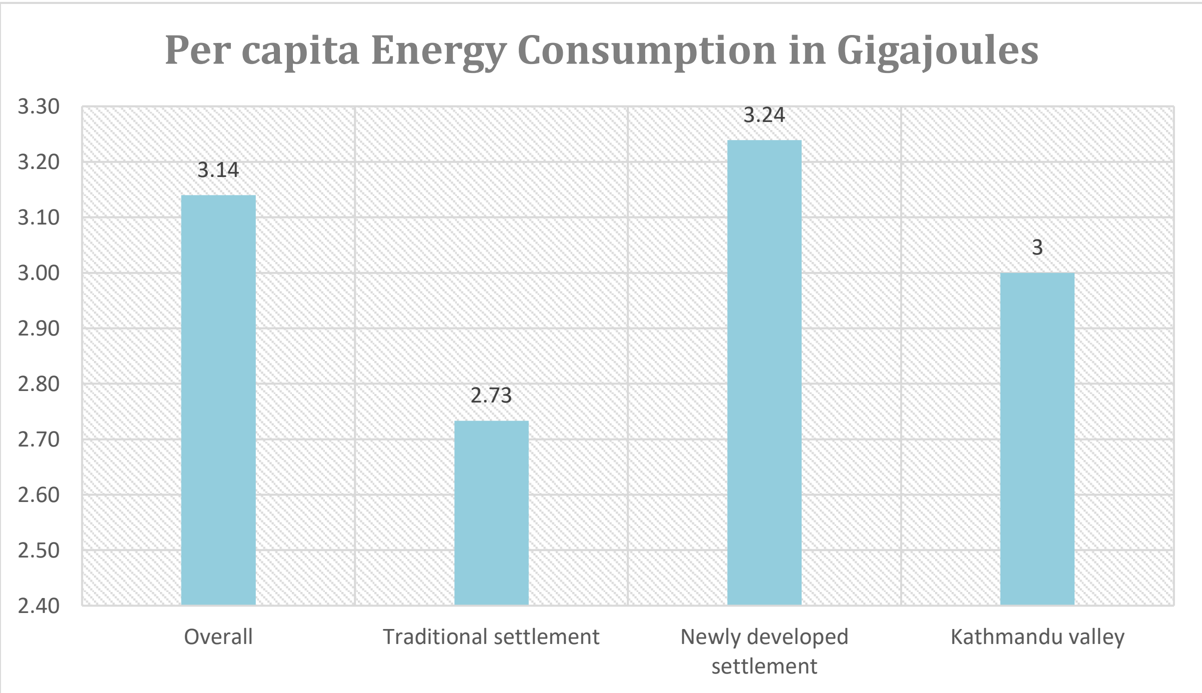

Figure 14 Per capita energy consumption

4.1.2 Final Energy Demand by End Use

Figure 15 shows the final energy demand by end use type. It is seen that cooking is the most energy intensive end-use which accounts for 51% of total energy demand. It is followed by electrical appliances (30%), Lighting (9%) and Alcohol Preparation (5%). Space heating and space cooling accounts 2% and 1% total energy consumed.

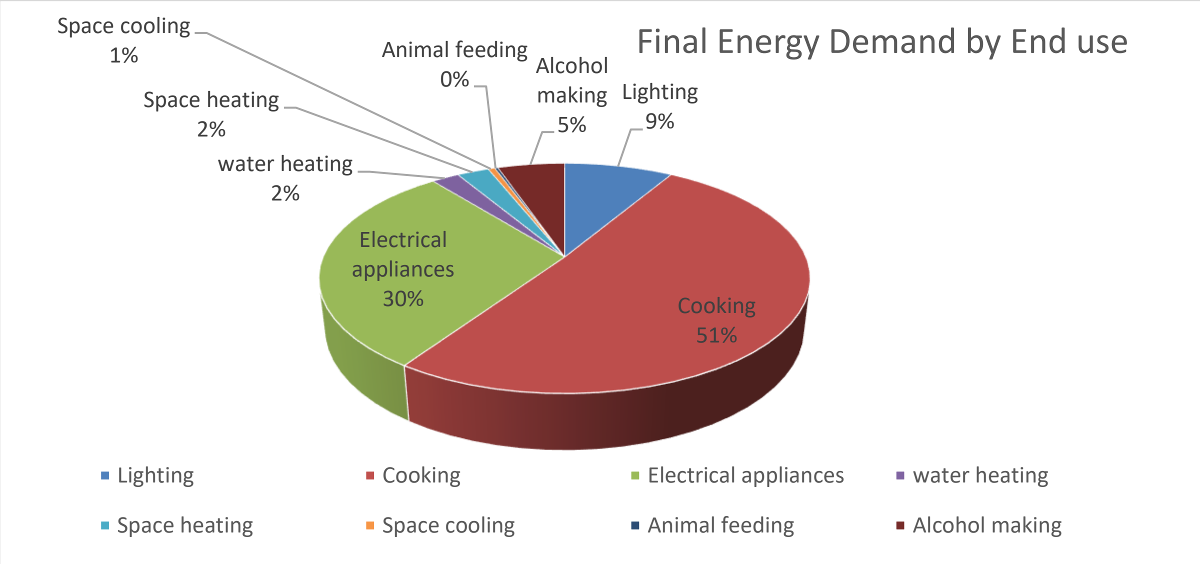

Figure 15: Final Energy Demand by End Use

4.1.3 Final energy demand by Fuel Types

Figure 16 shows the final energy demand by Fuel type. It is seen that LPG is the most energy intensive fuel type which accounts for 50% of total energy demand. It is followed by electricity (45%), Agricultural residue (5%). From this chart we can see the most used fuel is LPG and electricity respectively.

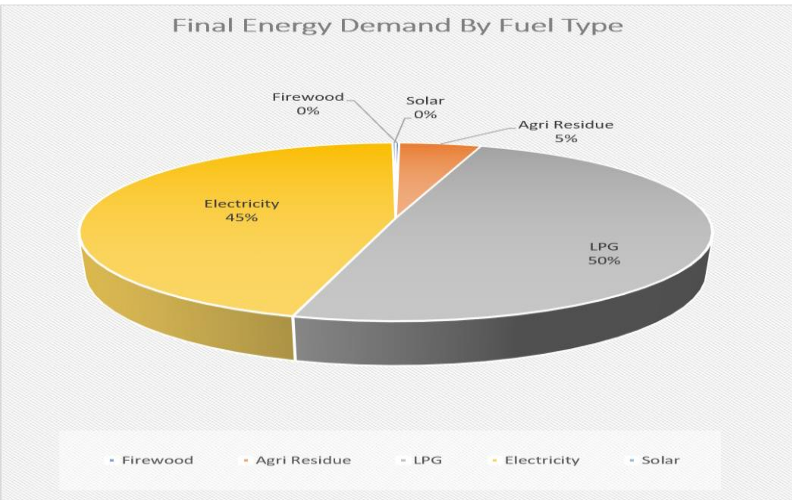

Figure 16: Final energy demand with Fuel types

4.1.4 Electricity User Ratio 5 AMP and 15 AMP

Figure-17 shows the electricity user ratio of 5 Ampere and 15 Ampere in Kirtipur municipality in both the settlements. From the chart,15 ampere (58%) electricity users are more than the 5 Ampere i.e. 42%. 26% of 5 Amp electricity users consumes 50Kwh – 250kwh per month. It shows that 53% of the NEA grid connection are to be upgraded to 15 A above connection for further policy intervention.

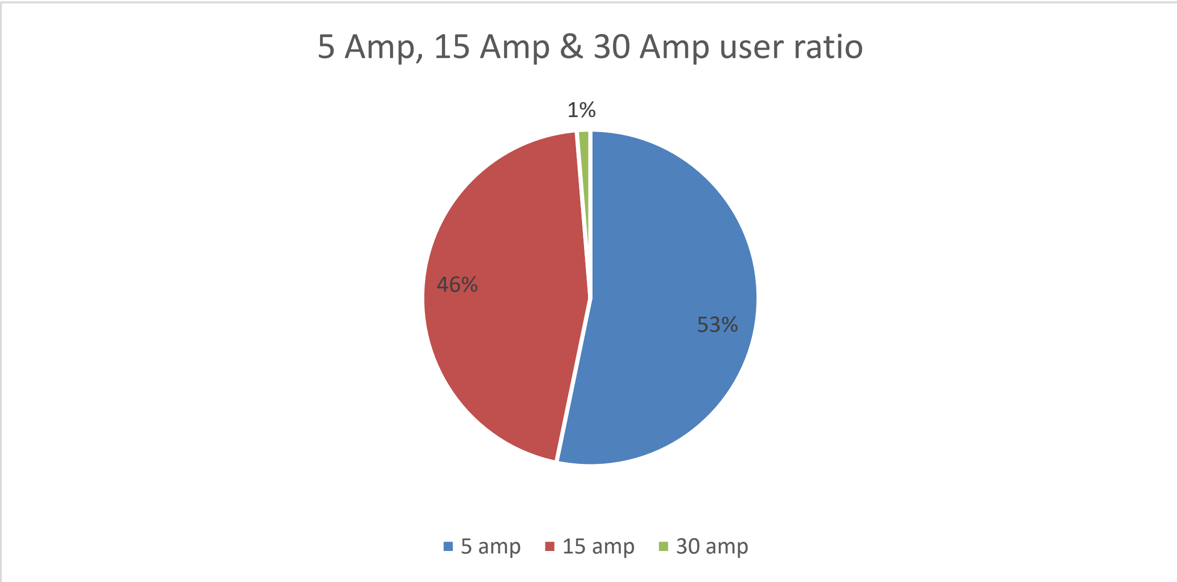

Figure 17 5 Amp, 15 Amp and 30 Amp user ratio

4.1.5 Candidates Interested in using Solar Home System

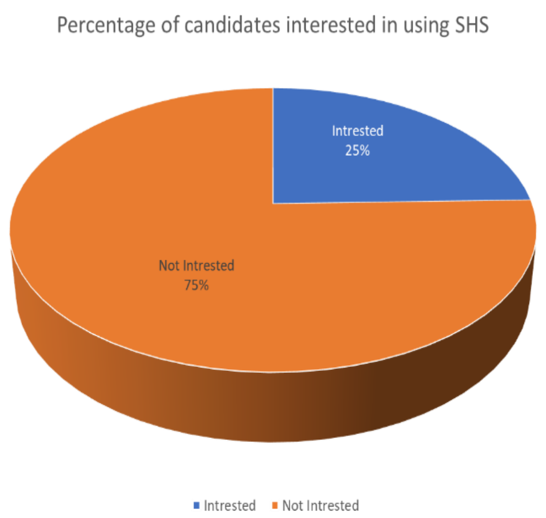

Figure 18 Candidates interested in using SHS

Figure 18 shows that the 75% of the household in Kirtipur municipality in both the settlements are not interested in using the Solar Home System and the remaining 25% are interested in using it which shows the moreover households are unaware of the renewable energy.

4.1.6 Electricity Consumption In 2018 (Kwh)

Figure - 19 shows the electricity consumed per household in 2018 in Kirtipur municipality between three different types of houses i.e. traditional houses, mixed use houses and modern houses. Electricity consumed per capita in traditional houses, mixed use houses and modern houses are 800.65 Kwh , 689.91 Kwh and 2586.24 Kwh respectively. The electricity consumed per household in Kirtipur Municipality is 1772.46 KwH in the year 2018.

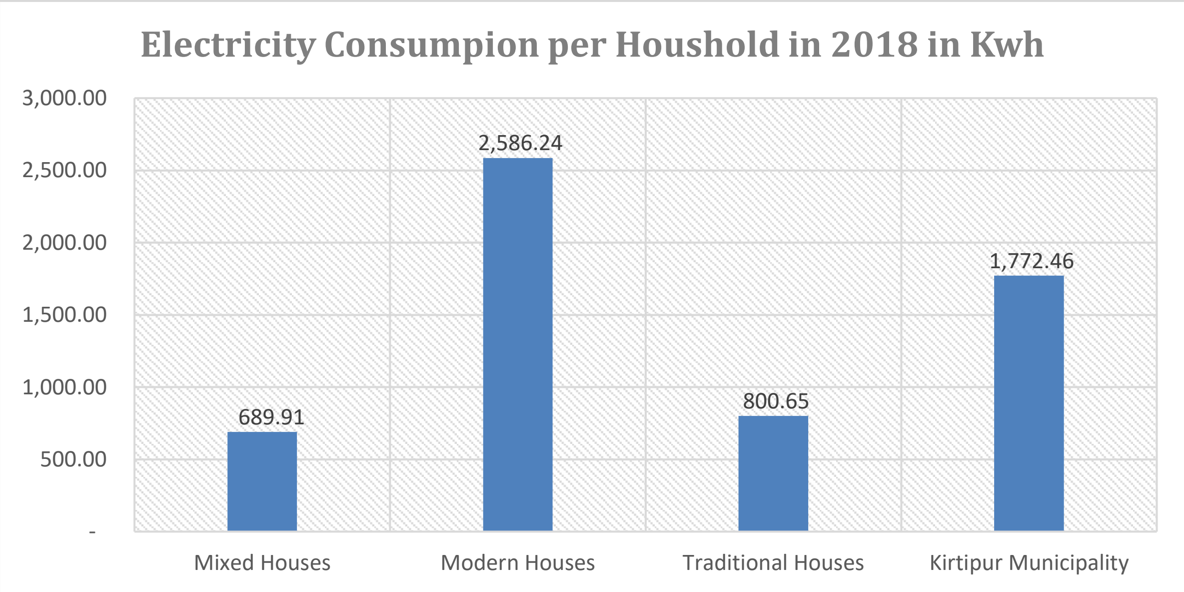

Figure 19: Electricity Consumption in 2018 (Kwh)

4.1.7. Energy Balance in 2018

Table 14 Energy Balance for Kirtipur municipality in 2018

Energy Balance for Area in 2018 "Kirtipur Municipality"						
Scenario: Current scenario, Year: 2018, Units: Thousand Gigajoule						
	Electricity	LPG	Wood	Solar	Agri-Resideu	Total
Production	-	-	1.1	3.3	13.6	18.0
Imports	142.1	129.9	-	-	-	272.0
Exports	-	-	-	-	-	-
Total Primary Supply	142.1	129.9	1.1	3.3	13.6	289.9
Transformation and Distribution	-28.4	-	-	-	-	-28.4
Total Transformation	-28.4	-	-	-	-	-28.4
Kirtipur Municipality	113.7	129.9	1.1	3.3	13.6	261.5
Total Demand	113.7	129.9	1.1	3.3	13.6	261.5

The energy balance of Kirtipur municipality for year 2018 show s that the total energy demand for Kirtipur municipality is 261.5 TJ. Total electricity import for Kirtipur municipality is 142.1 TJ with transmission and Distribution loss of 20%.

4.2 Scenario Analysis

This section shows the results of scenarios developed from the primary data survey and secondary data on demography, technologies and resources. The results of the scenario that have been analyzed are described to give the effects of certain policy and technologies interventions. Table- 15 shows the descriptions of the scenarios that have been developed in this study.

Table 15 Scenario Summaries

Scenario Name		Description
BAU	**Business as Usual**	▪ Population growth rate 4.47% which remains constant throughout the study period ▪ Energy intensity and energy mix remains the same.
EHE	**Electrification through Hydro Power Electricity Scenario**	▪ Population growth rate 4.47% which remains constant throughout the study period ▪ Promote access of electricity. ▪ LPG gradually replaced by clean source of energy like electricity and solar water heating by the year 2030 and continue to the year 2050. ▪ Minimal amount of traditional fuels in used are left as it is.
SDG	**Sustainable Development Goal Scenario**	▪ Population growth rate 4.47% which remains constant throughout the study period ▪ Traditional and fossil fuels will gradually replace by clean fuels: Electricity and solar PV in order to reduce GHGs and local air pollutants emission by the year 2030 and continue to the year 2050.

4.2.1. Business as Usual Scenario (BAU)

The Business as Usual Scenario where there are no interventions being done and Population growth rate is only the factors affection the final energy demand which is growing rapidly

4.2.1.1 Final Energy demand

The graph shows the energy demand in the Business as Usual (BAU) scenario from the base year 2018 to the end year 2050. The final energy demand for the base year 2018 was 261.5 TJ. From the graph it is clear that when the BAU scenario continues then then energy demand increases till the end year. This final energy demand in BAU scenario will increase constantly by the rate of 4.6% per annum from the base year value 261.5 TJ to 1101.4 TJ in the year 2050 as shown in figure below.

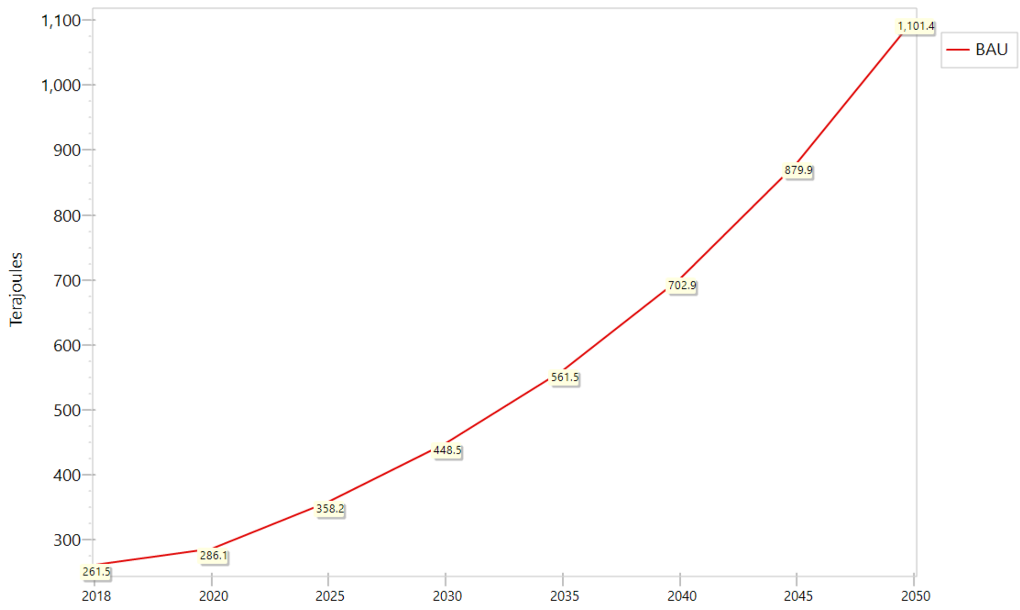

Figure 20 Final Energy Demand - BAU

4.2.1.2 Final Energy demand by Fuel Type

It can be seen that total energy demand will grow at the rate of 4.47% per annum and shares of energy mix will remain same as that of the base year 2018. The energy demand as per fuel types in BAU Scenario will be dominate by LPG and Electricity as in the base year in 2018 i.e. 527.2 TJ and 497.3 TJ respectively as shown in Table – 16.

Table 16: Final Energy demand by Fuel Type

Energy Demand by Fuel Types Final Units								
Scenario: BAU								
Branch: Demand								
Units: Terajoules								
Fuels	2018	2020	2025	2030	2035	2040	2045	2050
Electricity	113.7	124.7	157.1	197.9	249.2	313.8	395.1	497.3
LPG	129.9	141.7	176.4	219.6	273.4	340.3	423.5	527.2
Wood	1.1	1.2	1.5	1.9	2.5	3.2	4.1	5.2
Solar	2.9	3.2	4.2	5.5	7.1	9.3	12.0	15.6
Biomass	13.6	14.8	18.4	22.8	28.3	35.1	43.6	54.1
Solar Electricity	0.4	0.5	0.6	0.8	1.0	1.3	1.6	2.1

4.2.1.3 Final Energy demand per Capita

The Figure-21 shows the energy per capita in the BAU scenario from the base year 2017 up to end year 2050. In the BAU scenario, the energy per capita for base year is 2.9 GJ/capita and it may rise up to 3.1 GJ/capita by 2050.

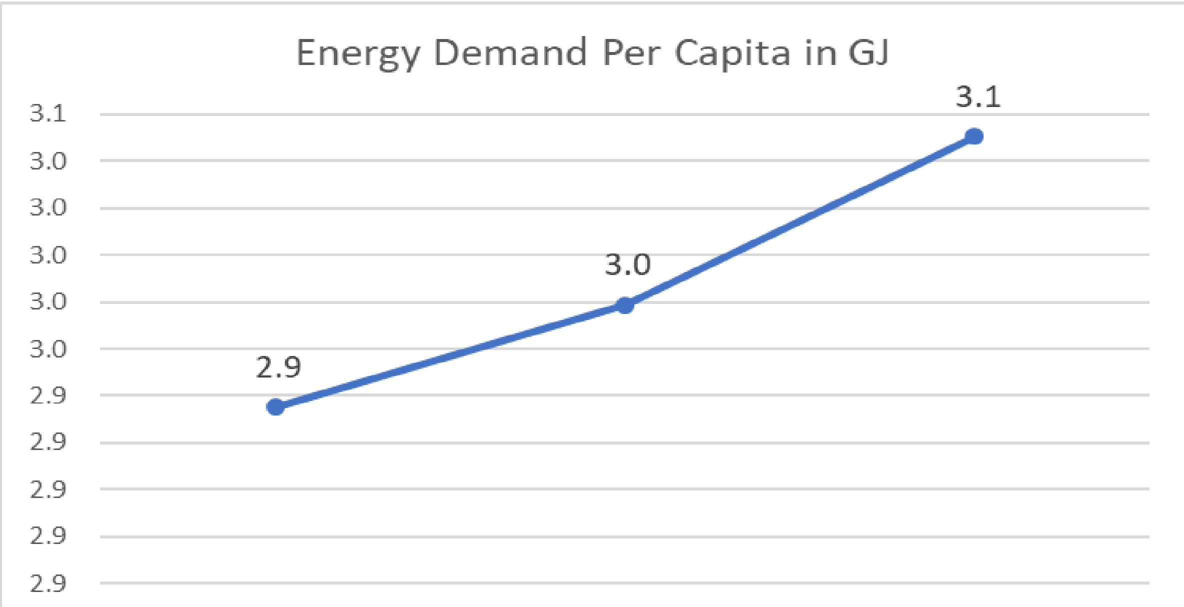

Figure 21 Final Energy demand per Capita

4.2.1.4 Electricity Demand Per Household in Kwh

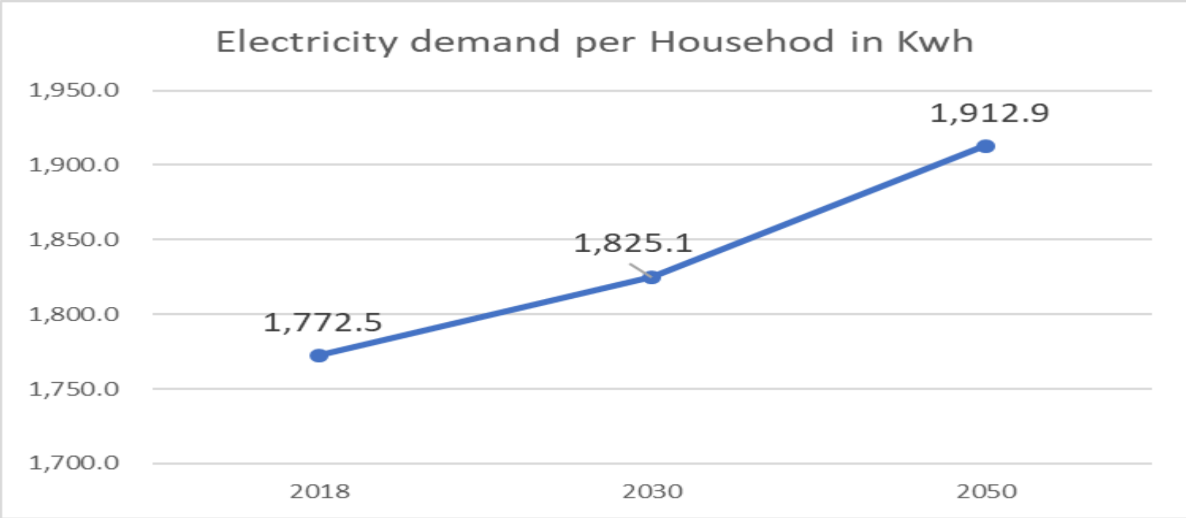

Figure 22: Electricity Demand per HH-BAU

As shown in Figure 28, the electricity demand per household in the base year 2018 is 1772.5 kWh per year which is needs to reach up to 3000 kwh by year 2030 to meet the multi-tier matrix of Sustainable development goal. From this chart we can see that if no interventions are made and the energy consumption patter in same as in the base year the multi-tier matrix cannot be meet by 2030 as shown in the char in BAU scenario by 2030 the electricity consumption per household per year will only be 1825.1 kwh.

4.2.1.5 Peak Powerplant Requirement

Figure 23 shows the power plant requirement for fulfilling demand in BAU scenario. In this scenario, electricity required in 2018 is 7.5 MW which will be gradually increase to 13 MW and 32.7 MW in year 2030 and 2050 respectively.

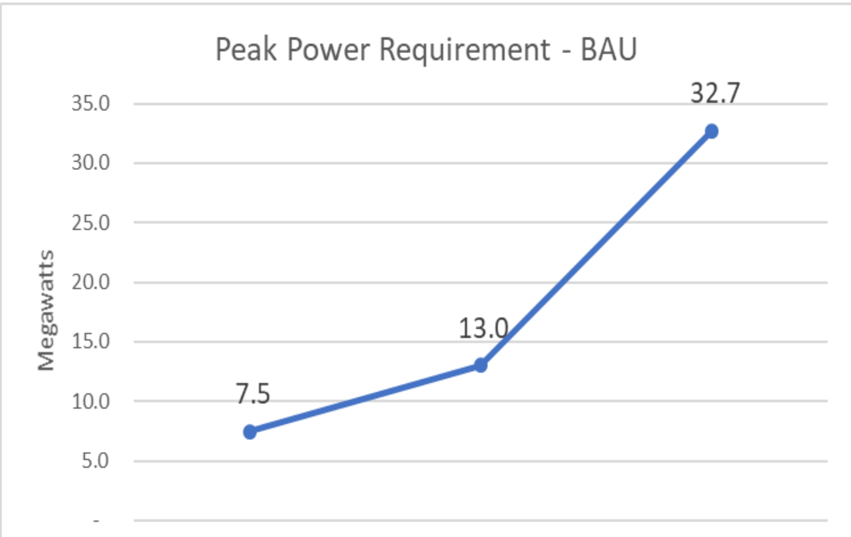

Figure 23 Peak Power plan Requirement - BAU

4.2.1.6 GHG Emission

Figure 24 shows the GHG emission due to combustion of different energy sources in residential sector. At the base year 2018 the GHG emission in BAU is 9.7 thousand metric tonnes carbon dioxide equivalent and 39.3 thousand metric tonnes carbon dioxide equivalent 2050.

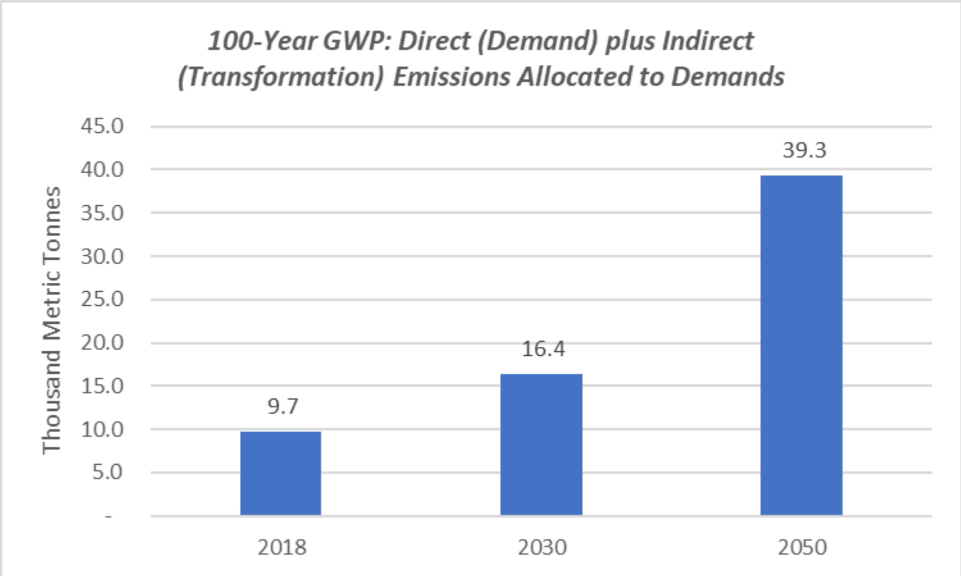

Figure 24: 100-Year GWP: Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands

4.2.2. Electrification by Hydro Electricity Scenario (EHE)

In the Electrification by Hydroelectricity Scenario LPG is 100% replaced by clean source of energy like electricity and solar water heating by the year 2030 and continue to the year 2050 and minimal amount of traditional fuels in used are left as it is. The EHE scenario looks after the future energy demand through the electrification by hydroelectricity.

4.2.2.1 Final Energy demand

The graph shows the energy demand in the Electrification by Hydro Electricity Scenario (EHE) from the base year 2018 to the end year 2050. The final energy demand for the base year 2018 was 261.5 TJ. From the graph it is clear that when the EHE scenario continues then then energy demand increases till the end year. This final energy demand in EHE scenario will increase constantly from the base year value 261.5 TJ to 1046.9 TJ in the year 2050 as shown in figure 25.

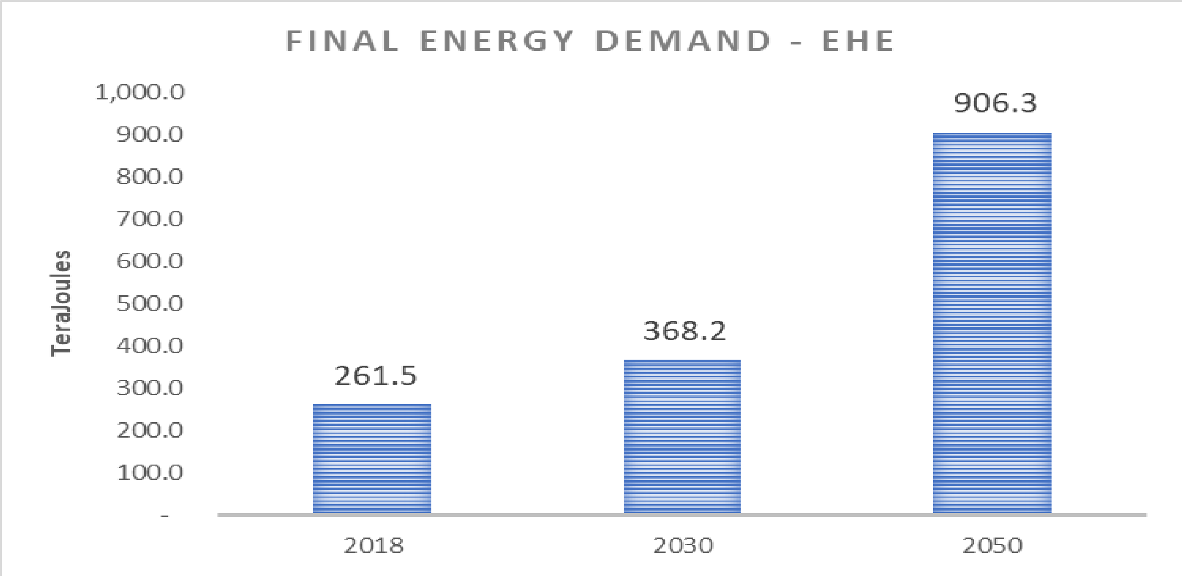

Figure 25: Final Energy demand, EHE

4.2.2.2 Final Energy demand by Fuel Type

Table -17 shows that total energy demand will grow and the energy demand as per fuel types in EHE Scenario will be dominate by Electricity and solar for water heating purpose. The Energy demand by fuel type in electricity will increase in the year 2030 to 2050 i.e. 328.89 TJ and 809.13 TJ and will for solar increase in the year 2030 to 2050 i.e. 71.46 TJ and 180.90 TJ respectively.

Table 17: Final Energy demand by Fuel Type, EHE

Energy Demand Final Units								
Scenario: EHE								
Branch: Demand								
Units: Thousand Gigajoules								
Fuels	2018	2020	2025	2030	2035	2040	2045	2050
Electricity	113.70	138.55	217.93	328.89	411.92	515.90	646.10	809.13
LPG	129.86	118.57	74.54	-	-	-	-	-
Wood	1.05	1.09	1.14	1.09	1.38	1.73	2.19	2.75
Solar	2.86	10.13	34.77	71.46	90.16	113.74	143.45	180.90
Biomass	13.61	14.84	18.41	22.84	28.33	35.14	43.60	54.08
Solar Electricity	0.44	0.41	0.26	-	-	-	-	-

4.2.2.3 Final Energy demand per Capita

The energy per capita in the EHE scenario from the base year 2018 up to end year 2050. In the EHE scenario, the energy per capita for base year is 2.9 GJ/capita and 2.9 GJ/capita for the rural for all the years as shown in the Figure – 26.

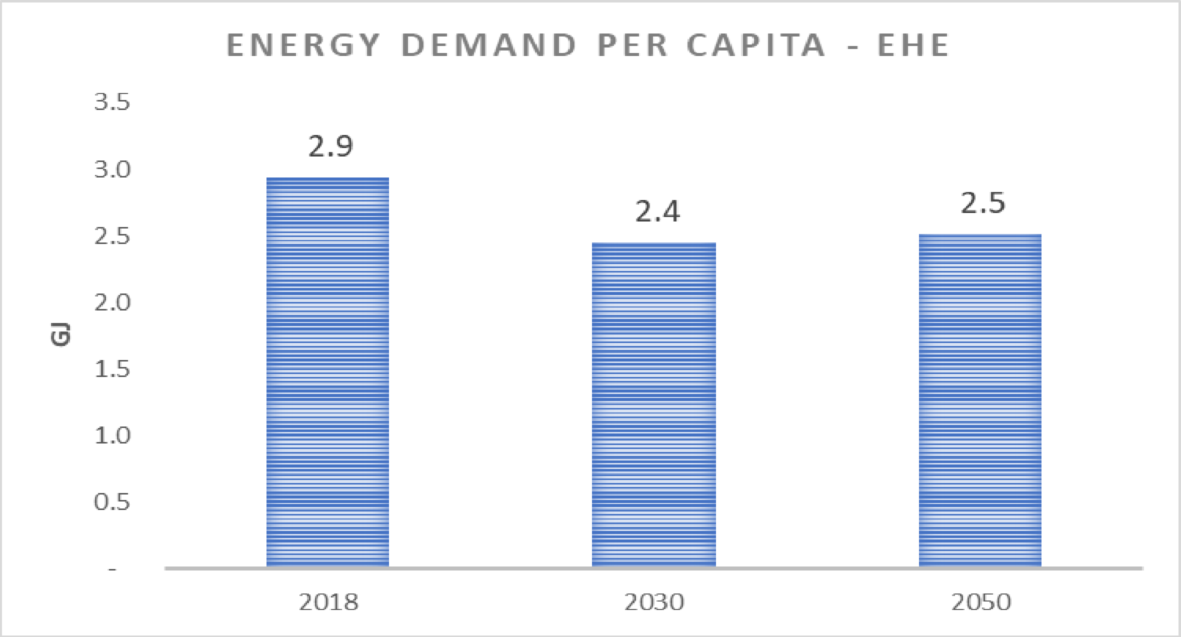

Figure 26 Final Energy demand per Capita, EHE

4.2.2.4 Electricity Demand Per Household in Kwh

As shown in Figure 27, the electricity demand per household in the base year 2018 is 1772.5 kWh per year which is needs to reach up to 3000 kwh by year 2030 to meet the multi-tier matrix of Sustainable development goal. From this chart we can see that if the all the fuels are replaced by the electricity and solar for water heating purpose the multi-tier matrix can be meet by 2030 which is 3033.6 Kwh per household per year and for the year 2050 will be 3112.4 Kwh per household per year.

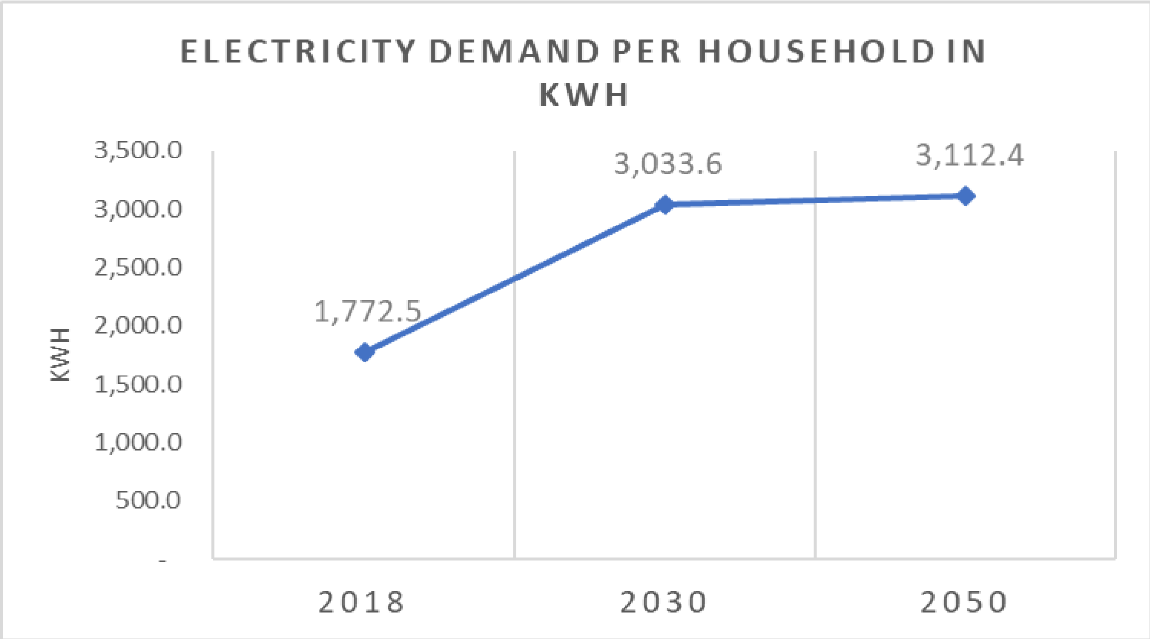

Figure 27: Electricity Demand Per Household in Kwh (EHE)

4.2.2.5 Peak Powerplant Requirement

Figure 28 shows the Peak power plant requirement for fulfilling demand in EHE scenario. In this scenario Peak powerplant required from the Hydropower in 2018 is 7.5 MW which will be gradually increase to 21.6 MW and 53.3 MW in year 2030 and 2050 respectively.

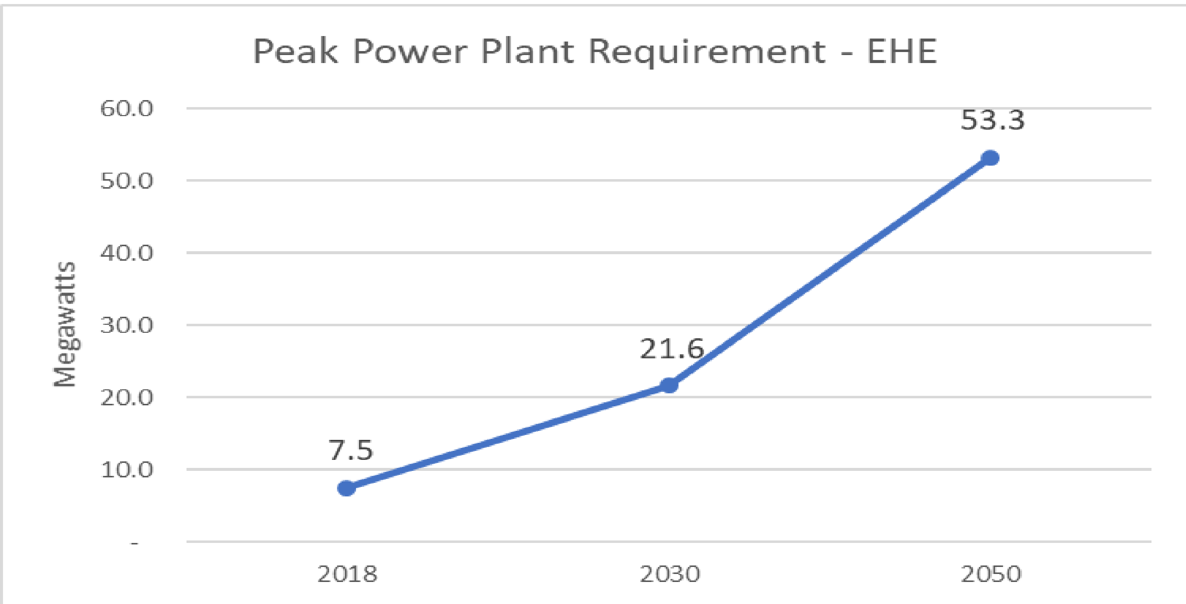

Figure 28: Peak Powerplant Requirement (EHE)

4.2.2.6 GHG Emission

Figure-29 shows the GHG emission due to combustion of different energy sources in residential sector. At the base year 2018 the GHG emission in EHE is 9675.8 metric tonnes of carbon dioxide equivalent, which can fully be decreased to 240.7 metric tonnes of carbon dioxide equivalent GHG emission from residential sector by the year 2030.

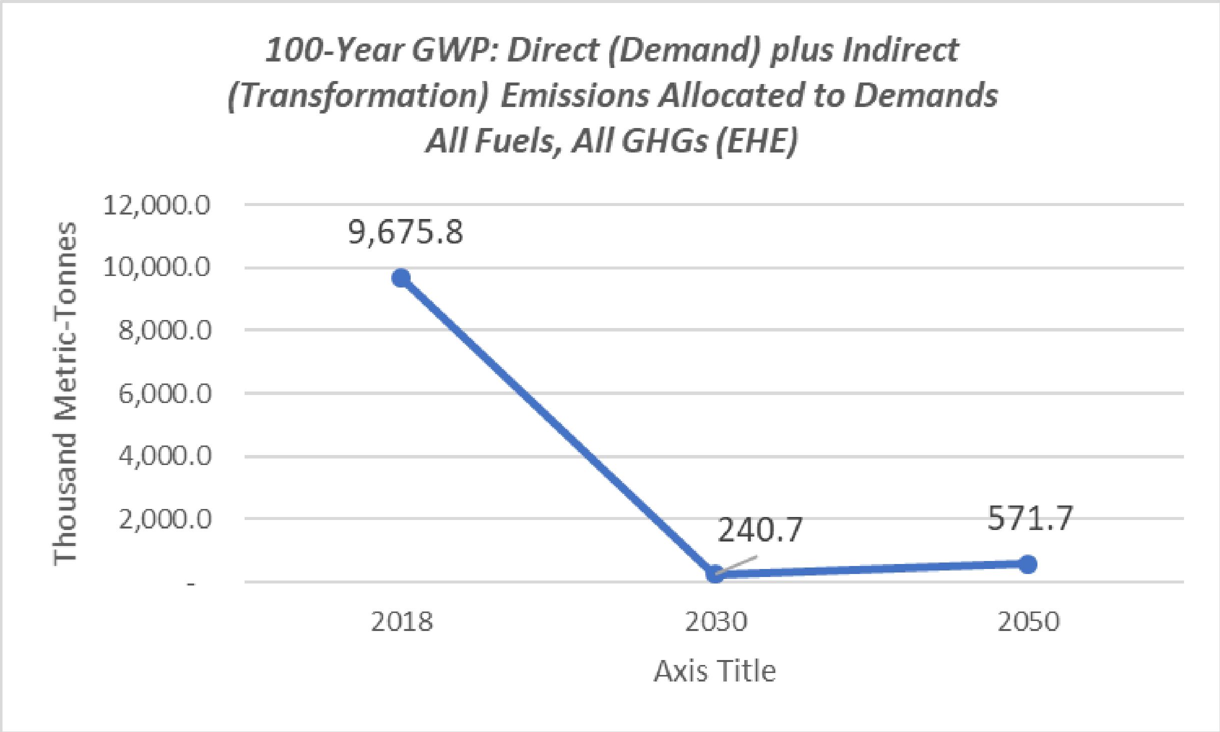

Figure 29: 100-Year GWP: Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands All Fuels, All GHGs (EHE)

4.2.3. Sustainable Development Scenario (SDG)

In the Electrification by Hydroelectricity Scenario LPG is 100% replaced by clean source of energy like electricity and solar water heating by the year 2030 and continue to the year 2050 and minimal amount of traditional fuels in used are left as it is. The EHE scenario looks after the future energy demand through the electrification by hydroelectricity.

4.2.3.1 Final Energy demand

The final energy demand for the base year 2018 is 261.5 TJ. From the graph it is clear that when SDG scenario continues then the energy demand increases till the end year. This final energy demand in SDG scenario will increase constantly from the base year value 261.5 TJ to 1046.9 TJ in the year 2050 as shown in Figure 30.

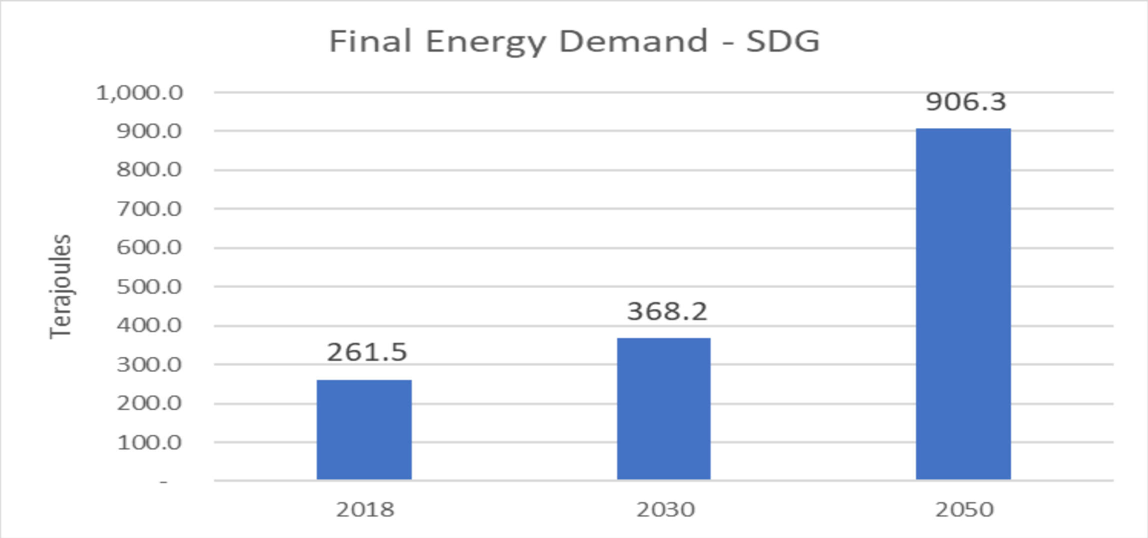

Figure 30: Final Energy demand (SDG)

4.2.3.2 Final Energy demand by Fuel Type

It can be seen that total energy demand will grow and the energy demand as per fuel types in SDG Scenario will be dominate by Electricity and solar for generating electricity. The Energy demand by fuel type in electricity will increase in the year 2030 to 2050 i.e. 171.25 TJ and 414.36 TJ and will for solar increase in the year 2030 to 2050 i.e. 157.63 TJ and 394.77 TJ respectively as shown in the Table- 18

Table 18 Energy Demand By Fuel Type in SDG Scenario

Energy Demand Final Units								
Scenario: SDG								
Branch: Demand								
Units: Terajoules								
Fuels	2018	2020	2025	2030	2035	2040	2045	2050
Electricity	113.70	122.21	145.38	171.25	213.59	266.39	332.23	414.36
LPG	129.86	118.57	74.54	-	-	-	-	-
Wood	1.05	1.09	1.14	1.09	1.38	1.73	2.19	2.75
Solar	2.86	10.13	34.77	71.46	90.16	113.74	143.45	180.90
Biomass	13.61	14.84	18.41	22.84	28.33	35.14	43.60	54.08
Solar Electricity	0.44	16.75	72.81	157.63	198.33	249.52	313.87	394.77

4.2.3.3 Final Energy demand per Capita

The graph shows the energy per capita in the SDG scenario from the base year 2018 up to end year 2050. In the SDG scenario, the energy per capita for base year is 2.9 GJ/capita and can be minimized up to 2.8 GJ/capita by 2030 and reach 2.9 GJ/capita in 2050 as shown in the Figure31

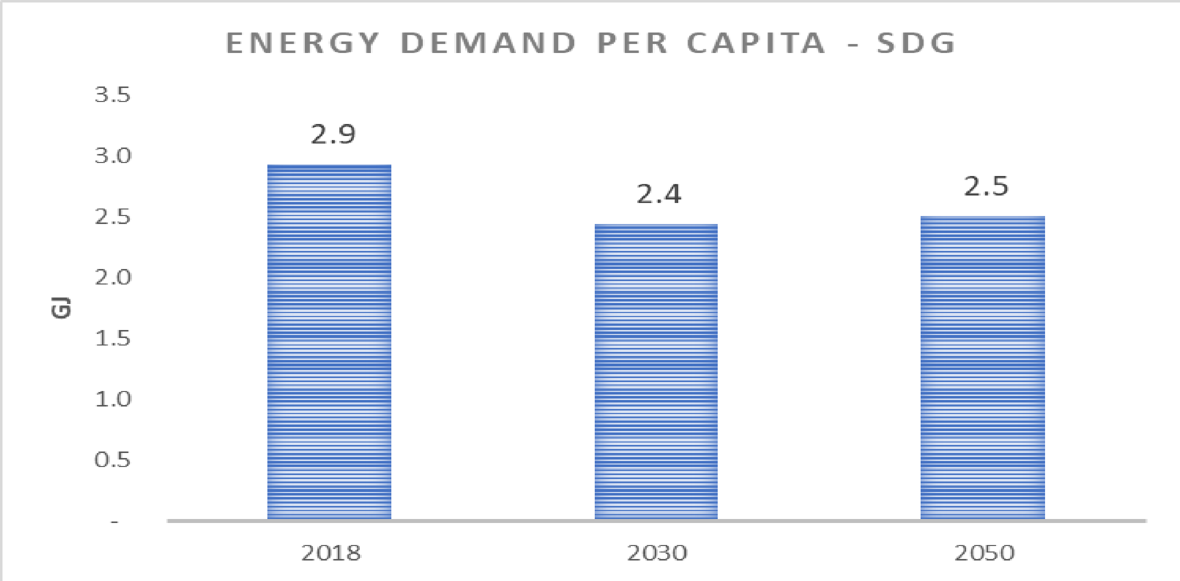

Figure 31 Final Energy demand per Capita (SDG)

4.2.3.4 Electricity Demand Per Household in Kwh

The electricity demand per household in the base year 2018 is 1772.5 kWh per year. From this chart we can see that if the all the fuels are replaced by the electricity and solar for water heating purpose, the electricity demand generated by hydropower by 2030 will be 1766.9 Kwh per household per year and for the year 2050 will be 1788.8 Kwh per household per year.

To reach up to 3000 kwh by year 2030 to meet the multi-tier matrix of Sustainable development goal, electricity demand is fulfilled by hydroelectricity and solar electricity in year 2030 where 1776.9 Kwh per household of electricity is provided from Hydropower (NEA) and 1266.7 Kwh per household of electricity is Generated from Solar home system (Solar pv). So the total electricity consumption per household is sum of the electricity from hydropower and solar PV which is 3033.6 Kwh per household in a year as shown in the Figure 32.

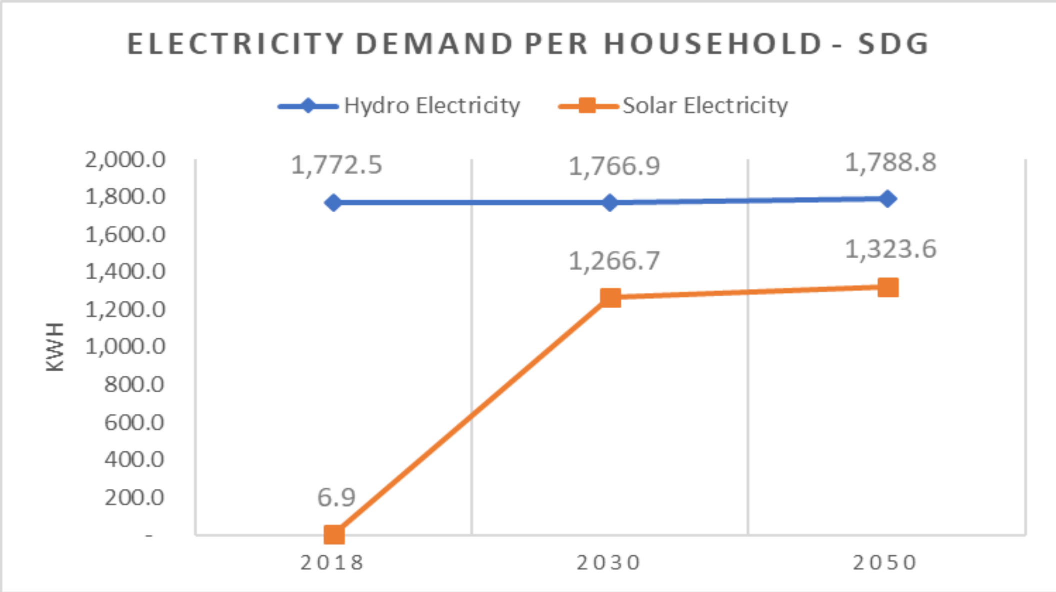

Figure 32: Electricity Demand Per Household in Kwh (SDG)

4.2.3.5 Peak Powerplant Requirement

Figure 33 shows the Peak power plant requirement for fulfilling demand in SDG scenario. In this scenario electricity required in 2018 is 7.5 MW which will be gradually increase to 11.3 MW and 27.3 MW in year 2030 and 2050 respectively.

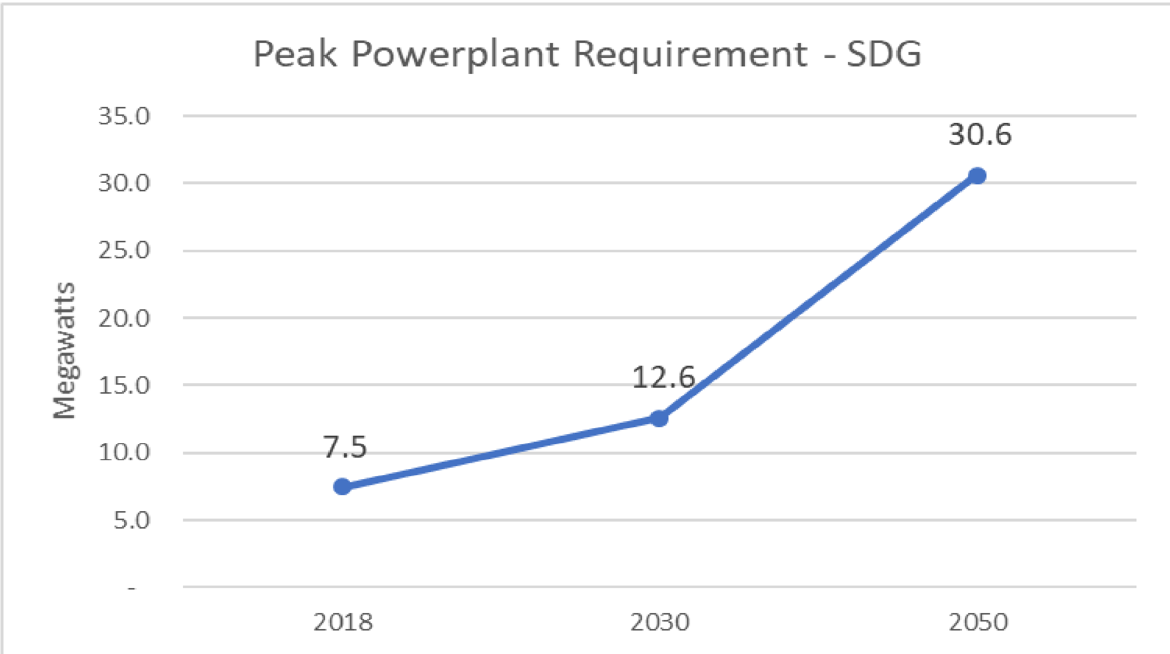

Figure 33: Peak Powerplant Requirement (SDG)

4.2.3.6 GHG Emission

Figure 41 shows the GHG emission due to combustion of different energy sources in residential sector. At the base year 2018 the GHG emission in EHE is 9675.8 metric tonnes of carbon dioxide equivalent, which can fully be decreased to 240.7 metric tonnes of carbon dioxide equivalent GHG emission from residential sector by the year 2030.

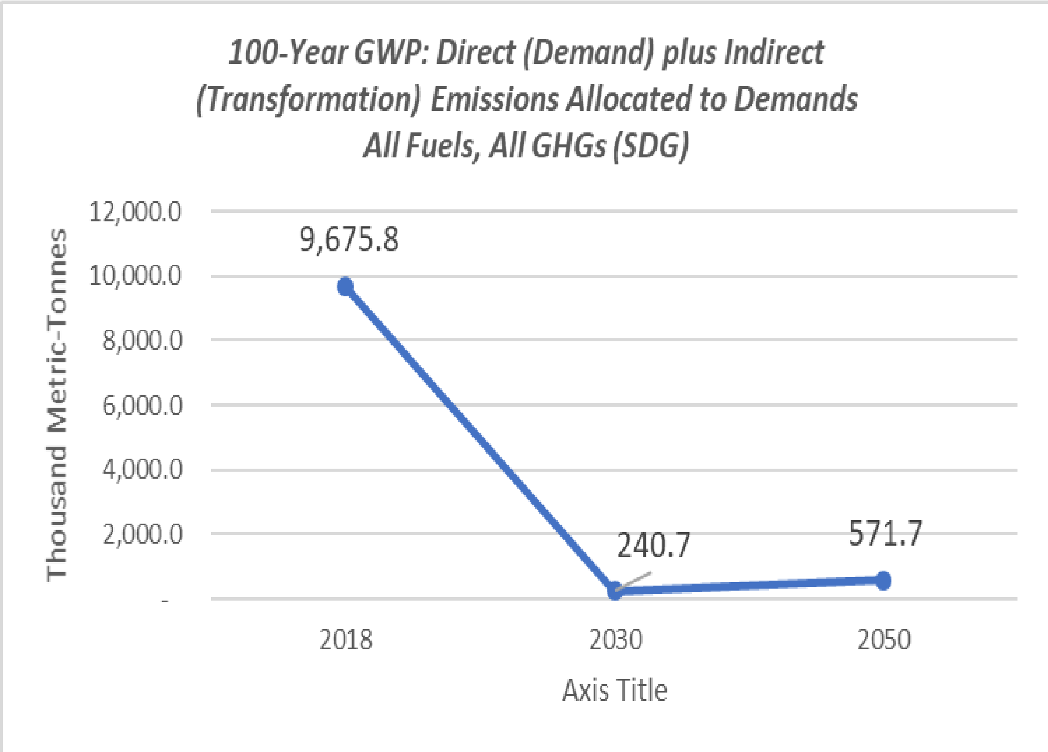

Figure 34: 100-Year GWP: Direct (Demand) plus Indirect (Transformation) Emissions Allocated to Demands (SDG)

CHAPTER 5: ANALYSIS AND DISCUSSION

The analysis and discussion section hold the Comparative Analysis of all three BAU, EHE and SDG scenario in terms of energy demand, fuel choice, electricity requirement and self-electricity generation from the Roof top solar PV. the further analysis is also done in term of economical fuel with the cost benefit analysis. The emission from the different fuels choice in three different scenarios are also looked after as the emission is also one of the important sector to be minimized in the energy planning. The model of Roof top solar PV for the typical contemporary house is designed for the electricity generation with concern its social values and social issues for the roof top solar PV in the case area.

5.1. Final Energy demand

The graph shows the energy demand in the Business as Usual (BAU) scenario and EHE scenario from the base year 2018 to the end year 2050. The final energy demand for the base year 2018 was 261.5 TJ. From the graph it is clear that when the BAU scenario continues then then energy demand increases till the end year. And if the EHE scenario continues then the energy demand increases from the base year value 261.5 TJ to 1046.9 TJ in the year 2050 as shown in figure 35. Energy consumption can be reduced to 424.3TJ from 448.5TJ by 2030 and 1046.9 TJ from 1101.4 TJ by the year 2050 switching different fuel to clean fuels and energy efficient technology.

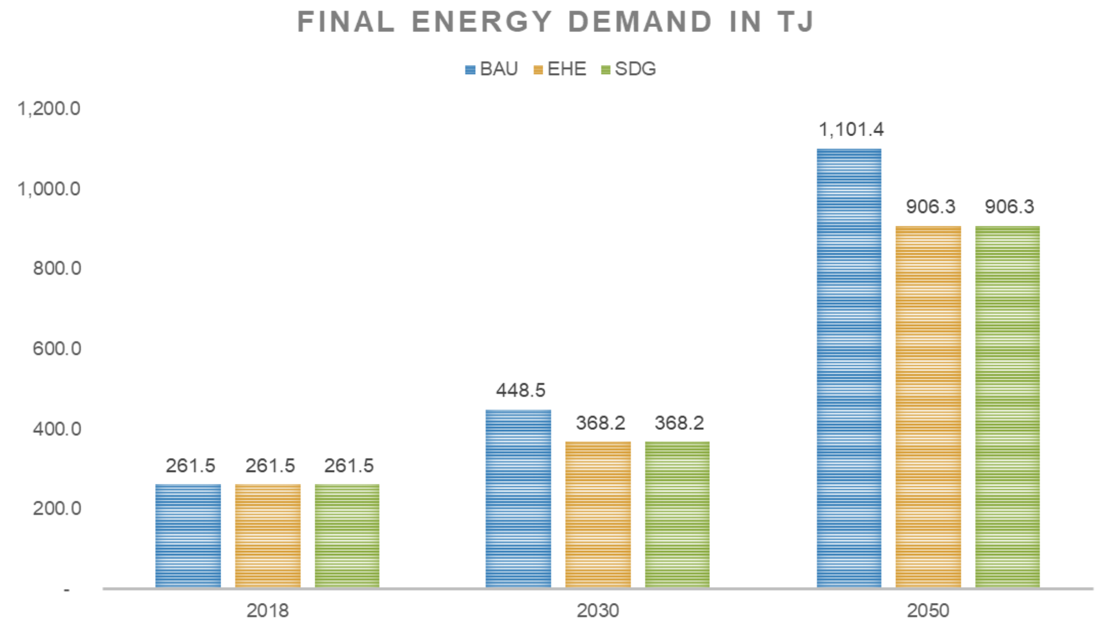

Figure 35: Final Energy Demand

5.2. Final Energy demand Per Capita

Figure - 36 shows the energy per capita in the BAU and EHE scenario from the base year 2017 up to end year 2050. In the BAU scenario, the energy per capita for base year is 2.9 GJ/capita and 3.1 GJ/capita for the rural for all the years. Energy consumption per capita can be reduced up to 0.6 GJ i.e. it will reduce from 3 GJ to 2.5 GJ by switching different fuel to Electricity in 2050.

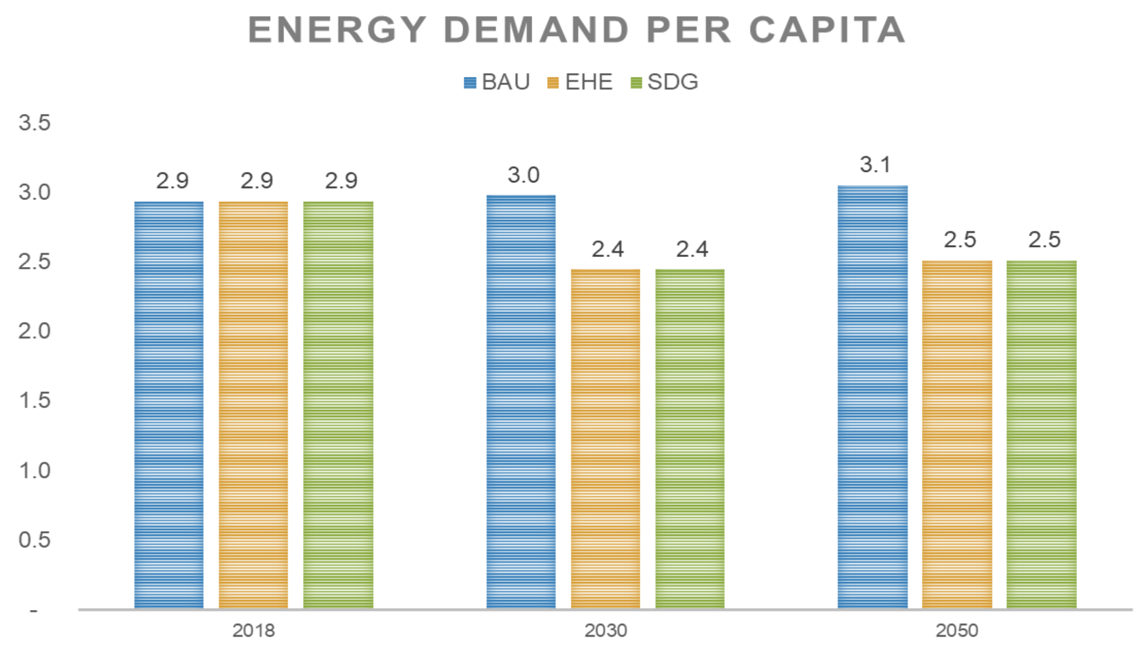

Figure 36: Final Energy demand Per Capita

5.3. Electricity Demand Per Household in Kwh

The electricity demand per household in the base year 2018 is 1772.5 kWh per year which is needs to reach up to 3000 kwh by year 2030 to meet the multi-tier matrix of Sustainable development goal. From this chart figure 44 we can see that if no interventions are made and the energy consumption pattern in same as in the base year the multi-tier matrix cannot be meet by 2030. If the all the fuels are replaced by the electricity and solar for water heating purpose and generating electricity it can meet the multi-tier matrix of Sustainable development goal reaching the electricity demand to 3033.6 Kwh per household.

But if the solar pv is used for the generation of electricity and used for lighting and electrical appliances purpose the electricity demand from the hydropower can be minimized up to 1542.3

kwh per household. From this chart figure 37 we can see that the implementation of solar pV can reduce up to 42 % of the electricity load from hydropower.

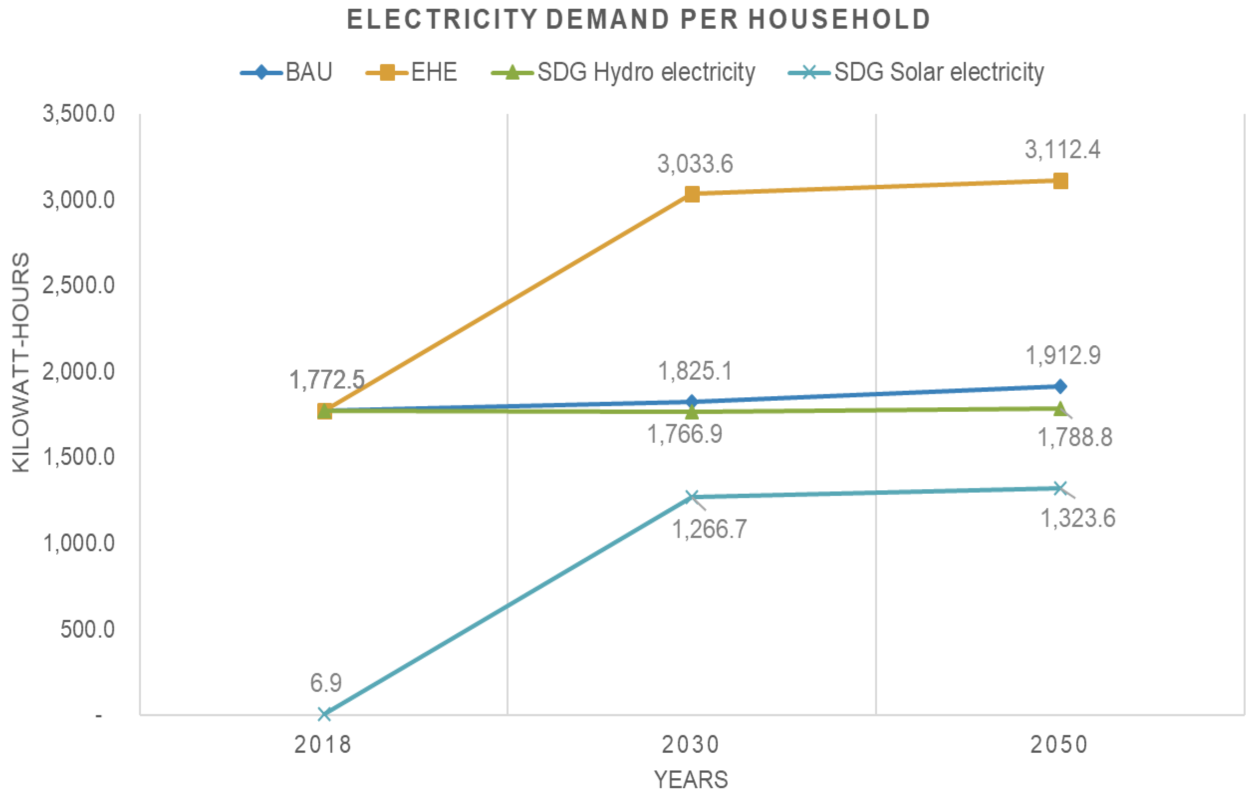

Figure 37: Electricity Demand Per Household in Kwh

5.4. Peak powerplant Requirement

Figure 39 shows the power plant requirement for fulfilling demand in BAU, EHE and SDG scenario. In BAU scenario, electricity required in 2018 is 7.5 MW which will be gradually increases up to 13MW and 32.7MW in 2030 and 2050 respectively. In EHE scenario electricity required will gradually increase to 21.6 MW and 53.3 MW in year 2030 and 2050 respectively. And in SDG scenario electricity required will gradually increase to 11.3 MW and 27.3 MW in year 2030 and 2050 due to switching to solar energy sources to lighting, 85% of electric appliances and water heating system the electricity is generate rom Roof top solar PV so the Peak power plant requirement is lower than in the EHE scenario in EHE all the electricity is supplied from the Hydropower.

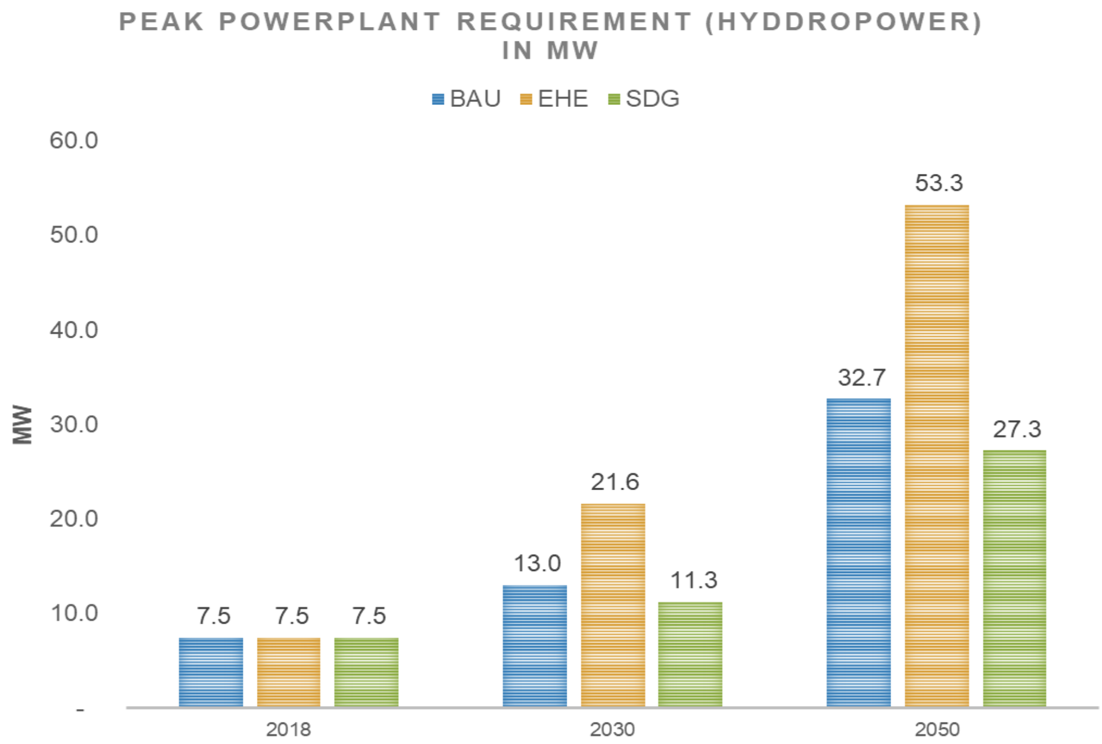

Figure 38: Peak powerplant Requirement (BAU, EHE and SDG)

5.5. Electricity Generation from Solar

Roof top solar PV is one of the possible renewable energy generation in household level. For the roof top solar PV, the total house from the CBS report 2011 further forecasted to 2030. From the total house the total house less than area of 50 Sqm were taken through the google maps as the house with the less than area of 50 sqm mostly need the terrace area for the self service uses like overhead water tank, drying clothes and solar water heater installation and the houses shaded by hills and other houses are also calculated using the google mas and SketchUp solar calculation from which the total number of eligible houses for rooftop solar PV is calculated which is 13876 number. The total available space for solar PV installation the average terrace area of the house of Kirtipur is taken which is 35 sqm out of which the 5.5 sqm is been left for the over head water tank and 2.6 sqm from the solar water heater so, the total average available space for roof top solar V is 26.9 sqm. Whereas the space needed for the 1Kwp solar panel is 10 sqm. The total electricity generated from the roof top solar pv in 2030 is 49046.9 Mwh in a year which is higher than the demand of 38417 Mwh in a year as shown in the Table -19.

Table 19 Electricity Generation from Solar PV

Total House in 2030	18701	Units
Total house less than area 50 sq m	4032	
Total houses shaded by hills	793	
Total eligible houses for SHS	187101 – 4032 - 793 = 13876	
Average terrace area of residential buildings:	35	Sqm
Average overhead tank space	5.5	Sqm
Average Solar water heater space	2.6	Sqm
Total available space for SHS in a house	35 – 5.5 – 2.6 = 26.9	Sqm
Total available space for SHS in Kirtipur municipality	20%	
Total available space for SHS in Kirtipur municipality	373264.4	Sqm
Space needed for 1kwp solar panel	10.0	Sqm
Total panel	37326.4	Kw
Final electricity generated by SHS (after availability factors)	5599.0	Kwh
	5.6	Mwh
Total electricity generated in year	5.6 x 8 760 =49046.9	Mwh
Total electricity generated in 1 house in a year	49046.9 / 13876 = 3534.66	Kwh

Final Electricity demand for SDG Scenario in 2030 in a year	91357	Mwh
Electricity Generated from SHS in kirtipur municipality in 2030 in a year	49046.9	Mwh
NEA grid load can be deducted up to	53.6%	
Solar Electricity required For SDG Scenario	47571	Mwh

If Solar PV is installed for the electricity generation in 2030. The 1kw solar home system with battery for storage costs Nrs.150000. with addressing the annual maintenance cost of 3% and life span of 25 years. The electricity generated from the solar cost Nrs.7 which is way cheaper than the levelized cost of electricity from NEA which is Rs.14.25. Table 20 shows that in 2030 if the electricity is generated from solar PV the Levelized cost of electricity can be half of the Levelized cost of electricity from NEA.

Table 20: Cost Benefit Analysis of 1kwp Solar PV in 2030

Cost Benefit Analysis of 1kwp Solar PV Cell			
Capacity	Cost	Discount Rate	Life
1kw	150,000 (IRENA 2012)	10%	25
Annuity	16525.21		
Annual Maintenance	495.76 (3% of Annuity)		
Total annual expense	17020.97		
Daily Electricity generation	6.67	Kwh (Efficiency 15%)	
Electricity generation	2433.33	Kwh per year	
Unit cost of electricity by solar in 2030	Rs.6.9		

Unit Cost of Electricity =	Rs.14.25 (increase rate 3%)

5.6. GHG Emission

GHG Emission can be gradually reduced from 9.7 Kilo tonnes = 106.9 Kg per capita to 0.2 kilo tonnes by switching to the cleaner energy like Electricity from hydropower and Solar PV as shown in Figure – 40.

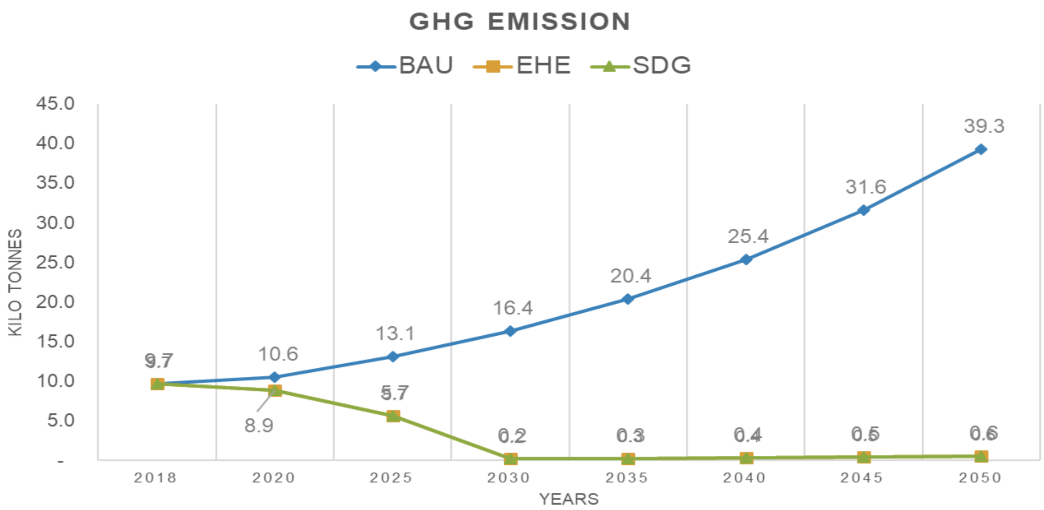

Figure 39: GHG Emission (BAU, EHE and SDG)

5.7. Typical Model House for Solar home installation

As per the bye laws of Kirtipur municipality, building coverage for every building is 70% and according to that most of the houses built, are of around 100 Sq.m. which includes two level of terraces: upper and lower terrace. Among which only lower terrace is used mostly by the residents for different activities such as drying clothes, sun bathe during winter, storage space etc. and the upper terrace is mostly used for overhead water tank, solar water heater and the remaining space is left unused. So, for this particular reason, the proposed model house design for the solar installation:

The lower terrace can be used for the services and activities such as drying clothes, sun bathe during winter, and other daily activities whereas the upper terrace with space allocated for the Solar water heater, Overhead Tank and Solar PV. The model house for the solar home installation is for both existing house and a new building house. The implementation of the roof top solar PV can be done by the awareness on renewable energy by the solar PV and its benefits

For existing Residences:

On average the average area of the upper terrace in houses of Kirtipur is 35 sq.m. The required area for the overhead tank is 5.5 sq.m and that for the solar water heater is 2.6 sq.m. and the remaining area of the upper terrace can be used for the Solar PV that can be used to generate electricity.

For New construction:

Use of Solar PV on the upper terraces utilizing the unused space should be incorporated in the bye laws with the awareness on renewable energy by the solar PV and its benefits.

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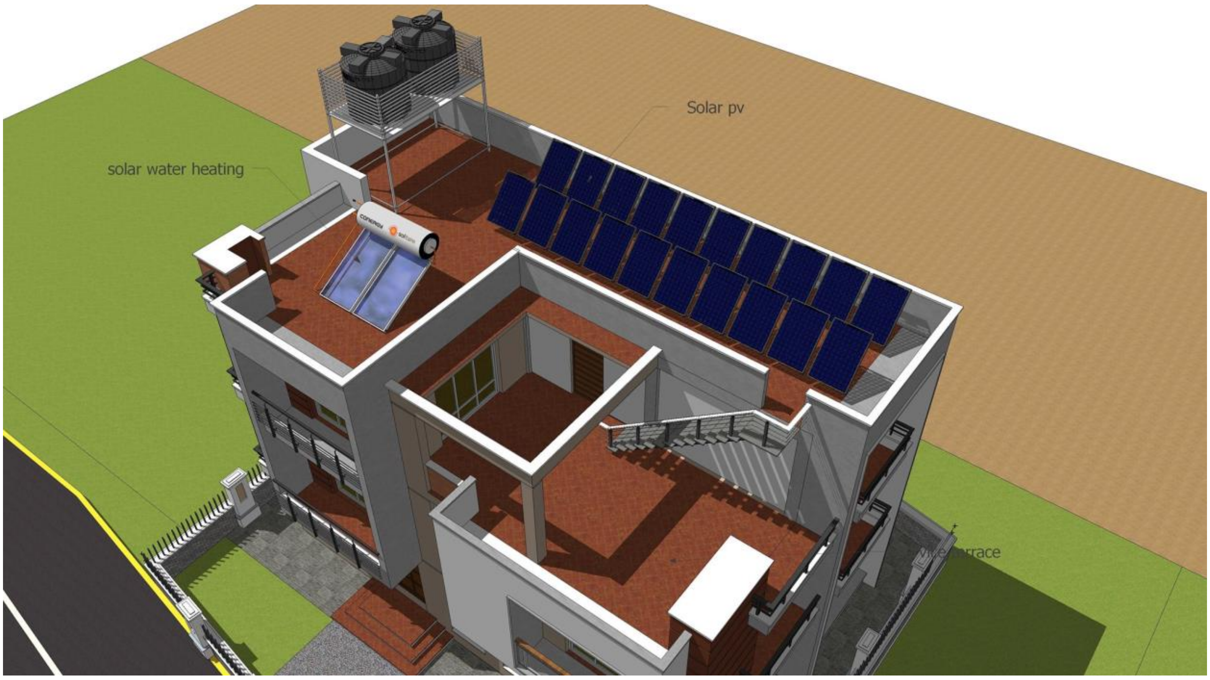


Figure 40: Typical Model House for Solar home installation

5.8. Energy Demand Cost Comparison

The sustainable energy development includes one of the important factors which is economy. Fr the sustainable energy development the energy cost should be minimum for the economic energy development. From the Figure 41 it can be seen that if none of the interventions are made as in the BAU scenario the energy demand cost in 2050 will reach up to 1008.9 Million Nepalese rupees by 2030 and 2484.2 million Nepalese rupees by 2050 which can be minimized by implementing the policy scenario intervention as in the SDG scenario and the energy demand cost can be minimized up to 213.6 Million Nepalese Rupees in 2030 and 532.8 Million Nepalese Rupees in 2050 than in the BAU scenario.

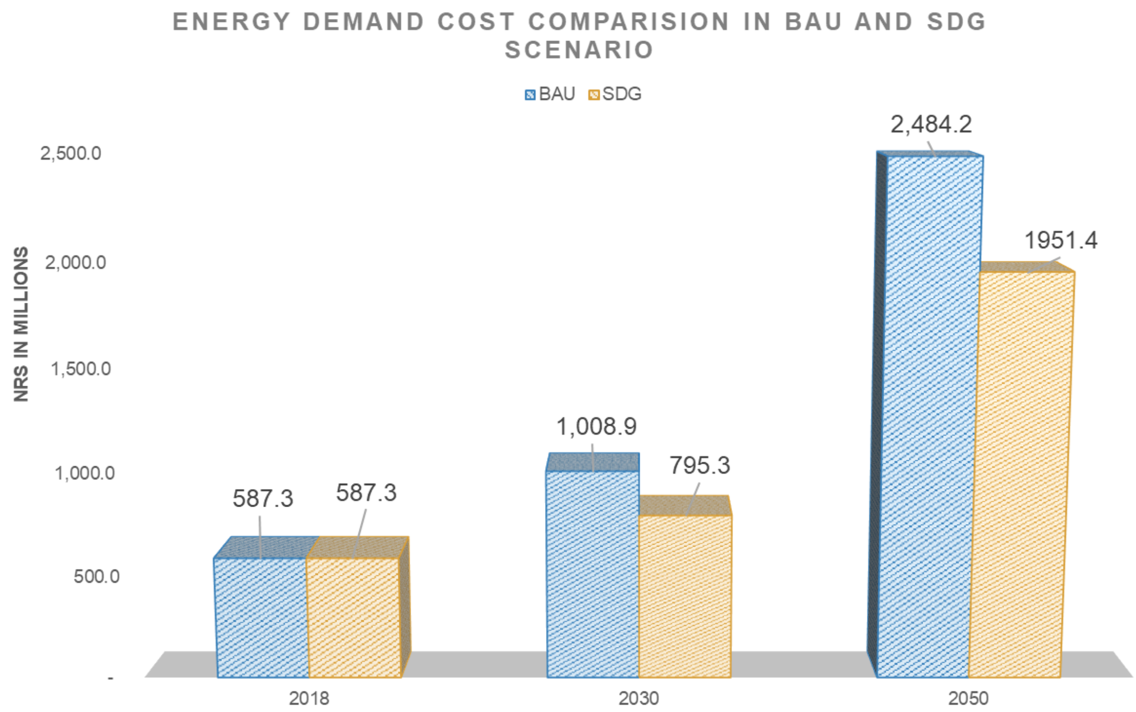


Figure 41 Energy Demand Cost Comparison in BAu and SDG Senario

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1. Conclusion

It has been a long time since Nepal has faced problems with the demand and supply of energy. More than a third of the population does not have access to electricity and is forced to depend on traditional fuels for energy requirements. The Residential energy consumption in Nepal is found to be around 80% as per the literature. Energy consumption pattern in case of Kirtipur municipality is found to be constantly increasing from the base year to the end in the study in BAU scenario. If any policy intervention is not introduced or intervened then the energy consumption will rapidly go on increasing. So, it is very important for the policy intervention especially in case of Nepal. As Nepal has the capacity to generate its own electricity, so the policy intervention should be accordingly for the sustainable future reducing the energy consumption.

It has been found that the total energy consumption of Kirtipur municipality was 261.5 TJ in the year 2018 accounting 2.9 GJ per capita. The energy demand will increase annually at the rate of 4.47% to 1101.4 TJ by 2050 if none of the interventions are made as in the BAU scenario where as in the EHE and SDG scenario the energy demand will reach up to 906.3 TJ resulting less final energy demand than in the BAU scenario.

Two scenarios EHE and SDG were developed with the fuel switching to clean energy and energy efficient technology i.e. Hydro Electricity, Solar electricity and Solar energy. This switching of fuels resulting to the less energy demand due to use of energy efficient technology. The SDG scenario moreover focuses on the electricity generation from the Rooftop Solar PV resulting to 54% of Total Electricity demand to be substituted by the electricity generated through the rooftop solar PV in the Kirtipur municipality. The self-generation of electricity from the solar PV not only minimize the NEA Grid Load but also provides the energy security.

The scenario analysis shows with the proper policy implementation and technology intervention the final energy demand can be reduced significantly. With availability and accessibility to cleaner and renewable energy the emissions can be reduced as well. The development of solar PV system and use of electricity can not only reduce the emission but also can significantly save the fuel expenditure.

6.2. Recommendation

Residential sector is the major energy consuming sector in case of Nepal. Since Kirtipur municipality has one of the higher population growth rates of 4.47% in the near future the not only the residential sectors there will also be need of more infrastructure and facilities as well in which energy plays the vital role for the fulfillment of infrastructure and facilities. There are also other sectors such as transportation, commercial, industrial and agriculture sector as well which are consuming energy so, the study of these sectors is also important in order to find the total energy demand of Kirtipur municipality. For the further finding of the total energy demand of Kirtipur municipality this research can be the part of further studies. The analysis of the emission is based on the only energy consumption in the residential sectors. the emissions from the other sectors as well can be undertaken for the further studies.

From the questionnaire and field visit it was found that the household had the NEA grid connection with the capacity of only 5A. For the policy intervention to be implemented as switching of fuels to the electricity these connections with the capacity 5A are to be replaced by the 15 A connection. Since 5A capacity connection is not enough for cooking in electricity by use of induction heater.

For the implementation of policy intervention, change in bye laws can be the part of further policy interventions implementation. The change in bye laws can be made as with the new construction of building there must be the compulsory of solar PV installation for the self-generation of energy as solar is the free source of energy.

Further street lights planning can be done for the sustainable energy planning at municipal level since there are no sufficient street lighting in the Kirtipur municipality whereas the street lights are one of the important factors in urban and energy planning.

The awareness programs on the benefits of the use of renewable energy and the effects from the imports fuel and its emission and its effects is one of the important factors for the implementation of use of roof top solar PV for the electricity generation in the Kirtipur municipality. The awareness on the switching of the technology which leads to the economical and emission less use of energy is also important for the people in the case area to understand for the implementation of the energy scenario planning

7. REFERENCES

1. Asian Development Bank. (2015). Energy Outlook for Asia and the Pacific. Manila: Asian Development Bank.
2. AEPC (2017). Technical specification for solar street lighting.
3. Basnet, B. D. (2017, Nov 21). Province 2 of Nepal: The Smallest Business-Rich Province. Retrieved from https://www.inheadline.com/news/province-2-of-nepal-the-smallest-business-rich-province
4. Bhatia, M., & Angelou, N. (2015). BEYOND CONNECTIONS Energy Access Redefined. Washington DC: The International Bank for Reconstruction and Development / THE WORLD BANK GROUP.
5. Bhandari, R. and S. Pandit (2018). "Electricity as a Cooking Means in Nepal—A Modelling Tool Approach." Sustainability 10(8): 2841.
6. Bhandari, R. and I. Stadler (2011). "Electrification using solar photovoltaic systems in Nepal." Applied Energy 88(2): 458-465.
7. CRT. (2005-06). National Energy Situation Survey Report Nepal - Focus on Renewable Energy & Poverty Reduction. Kathmandu.
8. CBS. (2011). Nepal Living Standards Survey 2010/11.Kathmandu: Central Bureau of Statistics, National Planning Commission Secretariat, Government of Nepal.
9. Efficiency, B. o. (n.d.). Material and Energy Balance. Bureau of Energy Efficiency.
10. Energypedia. (2016, May 3). Nepal Energy Situation. Retrieved from https://energypedia.info/wiki/Nepal_Energy_Situation
11. Energypedia (2017). "Nepal Energy Situation." from https://energypedia.info/wiki/Nepal_Energy_Situation.
12. Gautam, B. R., et al. (2015). "Assessment of urban roof top solar photovoltaic potential to solve power shortage problem in Nepal." Energy and Buildings 86: 735-744
13. Gwamuri, J. and S. Mhlanga (2012). "Design of PV solar home system for use in urban Zimbabwe." Plenary Paper Session I: Water: 147.
14. IEA. (2016). Nepal. Retrieved from www.iea.org: http://www.iea.org/countries/nonmembercountries/
15. Investment Board Nepal. (2018). Energy Demand Projection 2030: A MAED Based Approach. Kathmandu: Investment Board Nepal.

16. Ishak, I. S. and R. A. Alias (2005). Designing a strategic information system planning methodology For Malaysian institutes of higher learning (ISP-IPTA), Universiti Teknologi Malaysia.
17. IRENA (2012). Renewable Energy Technology: Cost analysis series. 1.
18. Jain, A., et al. (2015). "Clean, affordable and sustainable cooking energy for India." Council on Energy, Environment and Water (CEEW) Report.
19. Krejcie, R. V. and D. W. Morgan (1970). "Determining sample size for research activities." Educational and psychological measurement 30(3): 607-610.
20. Leach, G. (1992). "The Energy Transition." Energy policy 20(2): 116-123.
21. Madlener, R. and Y. Sunak (2011). "Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management?" Sustainable Cities and Society 1(1): 45-53.
22. Mishra, A. (2008). "Fuel for the clean energy debate: a study of fuelwood collection and purchase in rural India." SANDEE policy brief/South Asian Network for Development and Environmental Economics; no. 34-08.
23. Masera, O. R., et al. (2000). "From linear fuel switching to multiple cooking strategies: a critique and alternative to the energy ladder model." World development 28(12): 2083-2103.
24. National Planning Commission. (2017). Nepal's Sustainable Development Goals, Baseline Report, 2017. Kathmandu: Government of Nepal, National Planning Commission.
25. NEEP. (2015). Nepal Energy Efficiency Programme. Retrieved from http://energyefficiency.gov.np/article-component3
26. Pant, P. R. and D. Dangol (2009). "Kathmandu valley profile." Briefing Paper, Governance and Infrastructure Development Challenges in Kathmandu Valley.
27. Pokharel, P. D. (2017, Jan 14). Nepal is a country Endowed with High Potential for Alternative Energy Resources. Retrieved from www.spotlightnepal.com: https://www.spotlightnepal.com/2013/01/14/nepal-is-a-country-endowed-with-high-potential-for-alternative-energy-resources-pokharel/
28. Rajbhandari, U. S., & Nakarmi, A. M. (2014). Energy Consumption and Scenario Analysis of Residential Sector Using Optimization Model – A Case of Kathmandu Valley. Proceedings of IOE Graduate Conference, (pp. 476-483).

29. Raut, S. (2017, Sep 29). Kerosene usage by districts in province two of Nepal. Retrieved from http://codefornepal.org/en/2017/09/1940/
30. Secretariat, W. a. E. C. (2010). Energy Sector Synopsis Report.
31. Shrestha, S., & Nakarmi, A. M. (2015). Demand Side Managment for Electricity in Nepal: Nepal analysis using LEAP Modeling Framework. Proceedings of IOE Graduate Conference, 242-251.
32. Shrestha, R. M. and S. Rajbhandari (2010). "Energy and environmental implications of carbon emission reduction targets: Case of Kathmandu Valley, Nepal." Energy policy 38(9): 4818-4827.
33. The Official Portal of Government of Nepal. (2017). Energy Sector. Retrieved from www.nepal.gov.np: https://www.nepal.gov.np/NationalPortal/view-page?id=92
34. UNDP. (2018). SDGs National Report - Nepal. Retrieved from http://www.np.undp.org/content/nepal/en/home/library/sustainable-development-goals-national-report---nepal.html
35. UNDP. (2018). Sustainable Development Goals. Retrieved from http://www.np.undp.org/content/nepal/en/home/sustainable-development-goals.html
36. Water and Energy Commission Secretariat (WECS). (2010). Energy Sector Synopsis Report. Kathmandu: Water and Energy Commission Secretariat, Government of Nepal.
37. Water and Energy Commission Secretariat (WECS). (2013). Nepal's Energy Sector vision 2050. Kathmandu: Government of Nepal.
38. Water and Energy Commission Secretariat. (2017). Electricity Demand Forecast Report (2015-2040). Kathmandu: Water and Energy Commission Secretariat.
39. WECS. (2010). Energy Sector Synopsis Report. Government of Nepal.
40. WECS. (2012). Energy Sector synopsis report. Government of Nepal.
41. WECS. (2013). Energy Sector synopsis report. Government of Nepal.
42. WECS (2017). Energy Sector Synopsis Report. Government of Nepal.

APPENDIX 1: Questionnaire

Questionnaire for household energy survey – Jenish maharjan

(Section 1: General Information of the Respondent)

(S.N.)	(Questions)	(Circle in or write appropriate answer)	(Go to)
1.1	Name		
1.2	Contact number		
1.3	Gender	Male Female Third gender	
1.4	Age		
1.5	House typology	Traditional Modern Mixed use Others	
1.6	Settlement type	Traditional Newly developed	
1.7	Ward no / Sabik ward No.		
1.6	Have you given your house in rent?	Yes No	If yes. 1.7
1.7	Type of tenants	[ ] Family [ ]Single [ ]With friends (2 or more)	
1.8	Are there any commercial activities in the house?	Yes No	
1.9	From which ethnicity do you belong to?	Newar Brahmin Chhetri Others	
1.10	Average household income?	Below 15k 15k - 30k 30k - 45k 45k – 60k Above 60k	

(Section 2: Information on Energy Use)

(S.N.)	(Questions)	(Circle in or write appropriate answer)			(Go to)
2.1	(What source do you use for lighting?) (Priority) 0- (not in use) 1 - (primary source) 2- (secondary source) 3- (tertiary source)	(Priority)	(source)	Average usage per day/month	
			National electricity grid line		
			Mini/Micro/ Pico hydropower		
			Solar Home system		
			Solar micro grid		
			Wind power)		
			Solar wind micro grid		
			Battery operated lamp		
			Kerosene		
			Other (Specify)		

(S.N.)	(Questions)	(Circle in or write appropriate answer)				(Go to)
			Nos.	Watts	Usage (hours)	
2.2	Lighting	1. Incandescent				
		2. Tube light				
		3. CFL				
		4. LED				
2.3	Electrical appliances in use	1. TV- CRT				
		2. TV- LED				
		3. Radio				
		4. Computer				
		5. Laptop				
		6. Refrigerator				
		7. Water pump				
		8. Iron				
		9. Mobile				
		10. Washing machine				
		11. Fan				
		12. Air conditioner				
2.4	What electrical appliances do you want to use in near future?	1. TV- CRT 2. TV- LED 3. Radio 4. Computer 5. Laptop 6. Refrigerator 7. Water pump 8. Iron 9. Mobile 10. Washing machine				

2.5	What source do you use to cooking?	(Priority)	source	(How Much per month?)				(Monthly expenses in NRS)
				(unit)	(Quantity)	Average usage (hr)	(Time spent for collection)	
	(Priority) 0- (not in use) 1 - (primary source) 2- (secondary source) 3- (tertiary source)		Animal dung	Kg				
			Firewood	Kg				
			Briquette	Kg				
			Kerosene	Liter				
			LPG gas	Nos.				
			Bio-gas	Cu.m.				
			Induction heater	kWh				
			Hot plate	kWh				
			Rice cooker	kWh				
			Other (Specify)					
2.6	What cooking technology do you want to use in near future to cook your meal?	1. Mud improved cook stove 2. Metallic ICS 3. Briquette stove 4. Kerosene stove 5. LPG gas 6. Bio-gas 7. Induction heater for cooking 8. Other (Specify)						

<table>
<tr><td rowspan="12">2.7</td><td rowspan="12">What source do you use to water heating?

(Priority)
0- (not in use)
1 - (primary source)
2- (secondary source)
3- (tertiary source)</td><td rowspan="2">(Priority)</td><td rowspan="2">source</td><td colspan="4">(How Much per month?)</td><td rowspan="2">(Monthly expenses in NRS)</td></tr>
<tr><td>(unit)</td><td>(Quantity)</td><td>Average usage (hr)</td><td>(Time spent for collection)</td></tr>
<tr><td></td><td>Animal dung</td><td>Kg</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Firewood</td><td>Kg</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Briquette</td><td>Kg</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Kerosene</td><td>Liter</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>LPG gas</td><td>Nos.</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Bio-gas</td><td>Cu.m.</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Induction heater</td><td>kWh</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Hot plate</td><td>kWh</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Solar water heater</td><td>liter</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Other (Specify)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2.8</td><td>What cooking technology do you want to use in near future for water heating?</td><td colspan="7">1. Mud improved cook stove
2. Metallic ICS
3. Briquette stove
4. Kerosene stove
5. LPG gas
6. Bio-gas
7. Induction heater for cooking
8. Solar water heater
9. Other (Specify)</td></tr>
</table>

2.9	What source do you use to space heating? (Priority) 0- (not in use) 1 - (primary source) 2- (secondary source) 3- (tertiary source)	(Priority)	source	(How Much per month?)				(Monthly expenses in NRS)
				(unit)	(Quantity)	Average usage (hr)	(Time spent for collection)	
			Animal dung	Kg				
			Firewood	Kg				
			Briquette	Kg				
			Kerosene	Liter				
			LPG heater	Nos.				
			Bio-gas	Cu.m.				
			Electric heater	kWh				
			Hot plate	kWh				
			Solar water heater	liter				
			Other (Specify)					

2.10	What cooking technology do you want to use in near future to cook your meal?	1. Mud improved cook stove 2. Metallic ICS 3. Briquette stove 4. Kerosene stove 5. LPG gas 6. Bio-gas 7. Induction heater for cooking 8. Other (Specify)

2.11	What source do you use to cook for animals? (Priority) 0- (not in use) 1 - (primary source) 2- (secondary source) 3- (tertiary source)	(Priority)	source	(How Much per month?)				(Monthly expenses in NRS)
				(unit)	(Quantity)	Average usage (hr)	(Time spent for collection)	
			Animal dung	Kg				
			Firewood	Kg				
			Briquette	Kg				
			Kerosene	Liter				
			others	Nos.				

3. Information of energy technologies

(S.N.)	(Questions)	(Circle in or write appropriate answer)	
3.1.1	(Please give us information about cook stove type and use in your house) (use of cookstove) 1 - (making meal) (water heating) 2 - (making animal meal) 3 - (tea and snacks preparation) 4 – (alcohol preparation) 5 - (heating purpose)	(Stove types)	(use of cookstove)
		Traditional cook stove	
		Husk stove	
		Improved cookstove	
		improved metallic cookstove	
		kerosene cookstove	
		Biogas	
		electrical heater	
		Rice cooker	
		LPG	
		Other (Specify)	

3.1.2	where do you bring fuelwood from? (fuelwood collection schedule) 1 -(everyday) 2 - (once a week) 3 - (once a month) 4 - (once a year) 5 - (when required)	Firewood collection from	(fuelwood collection)		
			(Time required in hours)	(distance in km)	(schedule)
		community forest			
		local market forest			
		government forest			
		own farm			
		private forest			
		Other (Specify)			

3.Solar home system

(S.N.)	(Questions)	(Circle in or write appropriate answer)	(Go to)
3.2.1	(Do you know about SHS?)	(Yes) (No)	
3.2.2	(Do you have installed SHS?)	(Yes) (No)	If yes Go to 3.2.7
3.2.3	(if not, are you interested to install SHS)	(Yes, interested) (Not interested)	
3.2.4	(if interested, can you invest to install SHS?)	(Yes, I can) (No, I cannot)	
3.2.5	(what type of support do you expect to install SHS?)	loan support for deficit amount) (loan support as well as subsidy) (require information) Other (Specify)	
3.2.6	(how much can you invest?) in NPR		
3.2.7	(Capacity of SHS) in watt peak		
3.2.8	(how is the performance of SHS?)	(Fully operational) (Non-operational) (Frequent operation issues) Other (Specify)	
3.2.9	(Are you satisfied with SHS?)	(Yes) (No)	
3.2.10	(how much did you pay to install SHS?) in NPR		
3.2.11	(Did you take loan to install SHS?)	(Yes) (No)	
3.2.12	(If you have taken loan, where did you take loan from?)	(Cooperative) (Bank) (friends, relatives) Other (Specify)	
3.2.13	(where do you take service when you face problem ?)		

3.National electricity grid

(S.N.)	(Questions)	(Circle in or write appropriate answer)	(Go to)
3.3.1	(How many hours of electricity supply you get from national electricity grid in a day?)	(less than 4 hours) (minimum 4 hours) (minimum 8 hours) (minimum 16 hours) (minimum 23 hours)	
3.3.2	(How many hours of electricity supply you get in evening?)	(less than 1 hours) (minimum 2 hours) (minimum 3 hours) (minimum 4 hours)	
3.3.3	(Is national electricity grid line reliable?) (less reliable): (more than 14 disruptions per week) (average reliable): (max 14 disruptions per week) (reliable): (max 3 disruptions per week of total duration <2 hrs.)	(less reliable) (average reliable) (reliable):	
3.3.4	(what size fuse do you have in your home?) in Ampere	5 16 32	
3.3.5	(Do you have any difficulties in operating electrical appliances due to voltage problem?)	(Yes) (No)	
3.3.5	(Do you have any financial difficulties to pay electricity tariff?)	(Yes) (No)	

(S.N.)	(Questions)	(Circle in or write appropriate answer)	(Go to)
3.4.6	(Where do you pay your electricity tariff?)	(electricity office or electricity staffs) (from prepaid meter) (Others, specify)	
3.4.7	(Any past accidents and possible risk associated with electricity supply?)	(Yes) (No)	

APPENDIX 2: Energy Balance

Energy Balance: BAU 2018

Energy Balance for Area "Kirtipur Municipality"							
Scenario: BAU, Year: 2018, Units: Thousand Gigajoule							
	Electricity	LPG	Wood	Solar	Biomass	Solar elc	Total
Production	-	-	1.1	2.9	13.6	0.5	18.0
Imports	142.1	129.9	-	-	-	-	272.0
Exports	-0.0	-	-	-	-	-	-0.0
Total Primary Supply	142.1	129.9	1.1	2.9	13.6	0.5	289.9
Roof top Solar	0.0	-	-	-	-	-0.0	-
electricity generation	-	-	-	-	-	-	-
Transformation and Distribution	-28.4	-	-	-	-	-	-28.4
Total Transformation	-28.4	-	-	-	-	-0.0	-28.4
Kirtipur Municipality	113.7	129.9	1.1	2.9	13.6	0.4	261.5
Total Demand	113.7	129.9	1.1	2.9	13.6	0.4	261.5

Energy Balance: BAU 2030

Energy Balance for Area "Kirtipur Municipality"							
Scenario: BAU, Year: 2030, Units: Terajoules							
	Electricity	LPG	Wood	Solar	Biomass	Solar elc	Total
Production	-	-	1.9	5.5	22.8	0.8	31.0
Imports	247.3	219.6	-	-	-	-	467.0
Exports	-	-	-	-	-	-	-
Total Primary Supply	247.3	219.6	1.9	5.5	22.8	0.8	498.0
Roof top Solar	-	-	-	-	-	-	-
electricity generation	-	-	-	-	-	-	-
Transformation and Distribution	-49.5	-	-	-	-	-	-49.5
Total Transformation	-49.5	-	-	-	-	-	-49.5
Kirtipur Municipality	197.9	219.6	1.9	5.5	22.8	0.8	448.5
Total Demand	197.9	219.6	1.9	5.5	22.8	0.8	448.5

Energy Balance: BAU 2050

Energy Balance for Area "Kirtipur Municipality"							
Scenario: BAU, Year: 2050, Units: Terajoule							
	Electricity	LPG	Wood	Solar	Biomass	Solar elc	Total
Production	-	-	5.2	15.6	54.1	2.1	76.9
Imports	621.6	527.2	-	-	-	-	1,148.8
Exports	-	-	-	-	-	-	-
Total Primary Supply	621.6	527.2	5.2	15.6	54.1	2.1	1,225.8
Roof top Solar	-	-	-	-	-	-	-
electricity generation	-	-	-	-	-	-	-
Transformation and Distribution	-124.3	-	-	-	-	-	-124.3
Total Transformation	-124.3	-	-	-	-	-	-124.3
Kirtipur Municipality	497.3	527.2	5.2	15.6	54.1	2.1	1,101.4
Total Demand	497.3	527.2	5.2	15.6	54.1	2.1	1,101.4

Energy Balance: EHE 2030

Energy Balance for Area "Kirtipur Municipality"						
Scenario: EHE, Year: 2030, Units: Terajoules						
	Electricity	Wood	Solar	Hydro	Biomass	Total
Production	-	1.1	15.4	-	22.8	39.3
Imports	0.0	-	-	411.1	-	411.1
Total Primary Supply	0.0	1.1	15.4	411.1	22.8	450.4
electricity generation	411.1	-	-	-411.1	-	-
Transformation and Distribution	-82.2	-	-	-	-	-82.2
Total Transformation	328.9	-	-	-411.1	-	-82.2
Kirtipur Municipality	328.9	1.1	15.4	-	22.8	368.2
Total Demand	328.9	1.1	15.4	-	22.8	368.2

Energy Balance: EHE 2050

Energy Balance for Area "Kirtipur Municipality"						
Scenario: EHE, Year: 2050, Units: Terajoules						
	Electricity	Wood	Solar	Hydro	Biomass	Total
Production	-	2.8	40.4	-	54.1	97.2
Imports	0.0	-	-	1,011.4	-	1,011.4
Total Primary Supply	0.0	2.8	40.4	1,011.4	54.1	1,108.6
electricity generation	1,011.4	-	-	-1,011.4	-	-
Transformation and Distribution	-202.3	-	-	-	-	-202.3
Total Transformation	809.1	-	-	-1,011.4	-	-202.3
Kirtipur Municipality	809.1	2.8	40.4	-	54.1	906.3
Total Demand	809.1	2.8	40.4	-	54.1	906.3

Energy Balance: SDG 2030

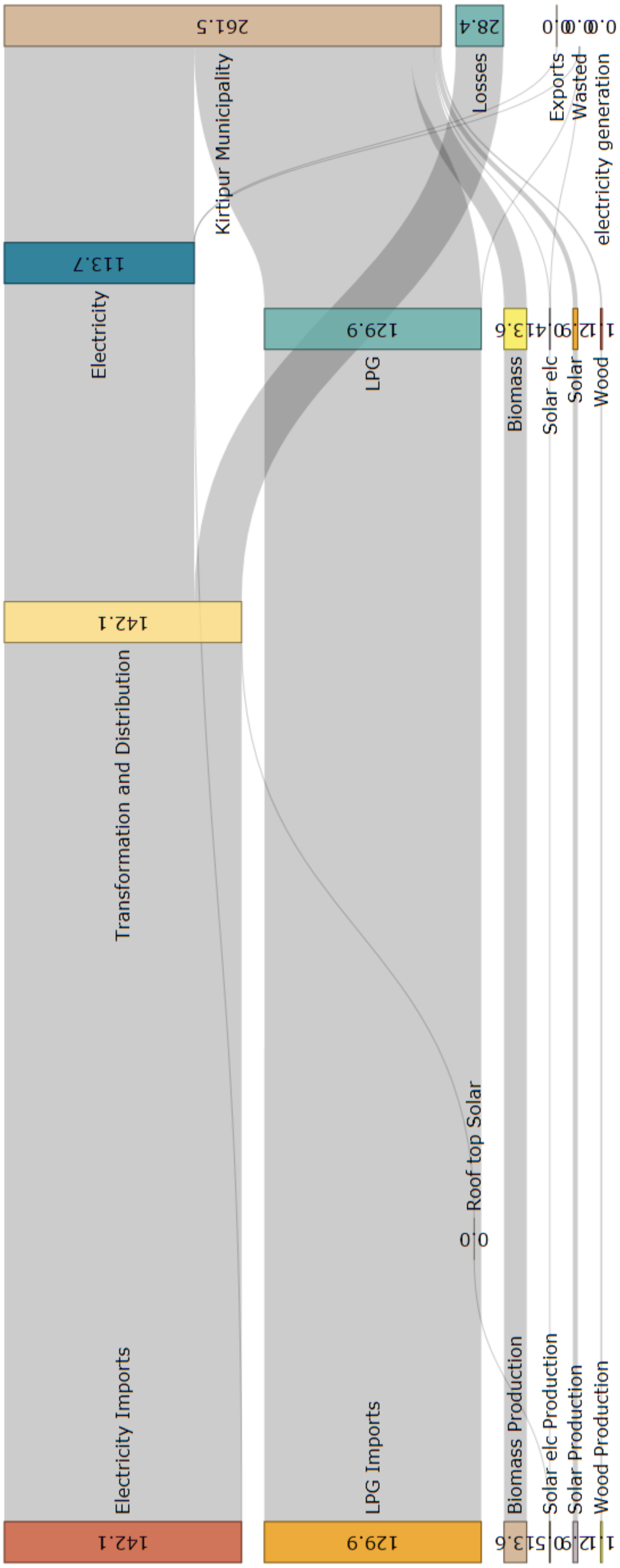
Energy Balance for Area "Kirtipur Municipality"							
Scenario: SDG, Year: 2030, Units: Terajoules							
	Electricity	Wood	Solar	Hydro	Biomass	Solar elc	Total
Production	-	1.1	152.7	-	22.8	-	176.6
Imports	0.0	-	-	239.4	-	-	239.4
Total Primary Supply	0.0	1.1	152.7	239.4	22.8	-	416.1
Roof top Solar	-	-	-137.3	-	-	137.3	-
electricity generation	239.4	-	-	-239.4	-	-	-
Transformation and Distribution	-47.9	-	-	-	-	-	-47.9
Total Transformation	191.6	-	-137.3	-239.4	-	137.3	-47.9
Kirtipur Municipality	191.6	1.1	15.4	-	22.8	137.3	368.2
Total Demand	191.6	1.1	15.4	-	22.8	137.3	368.2

Energy Balance: SDG 2050

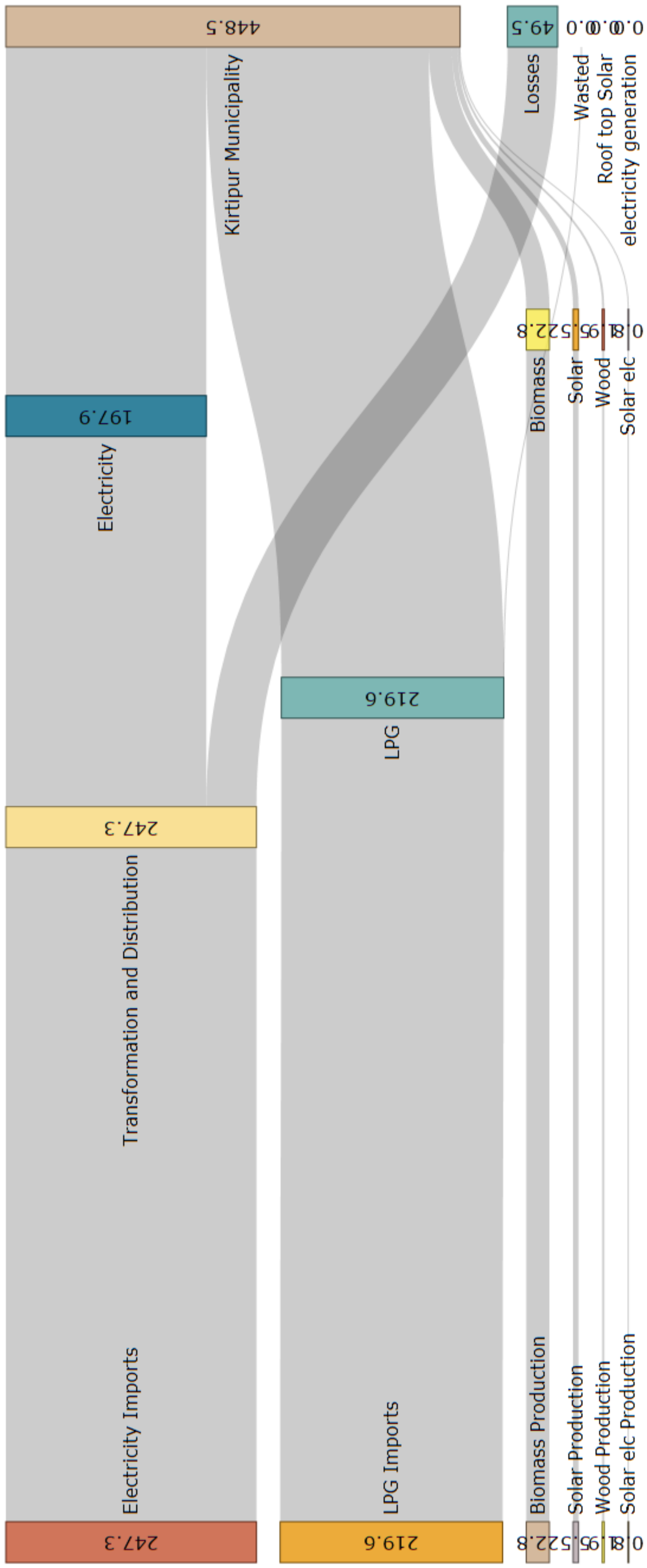
Energy Balance for Area "Kirtipur Municipality"							
Scenario: SDG, Year: 2050, Units: Terajoules							
	Electricity	Wood	Solar	Hydro	Biomass	Solar elc	Total
Production	-	2.8	384.5	-	54.1	-	441.3
Imports	0.0	-	-	581.3	-	-	581.3
Total Primary Supply	0.0	2.8	384.5	581.3	54.1	-	1,022.6
Roof top Solar	-	-	-344.1	-	-	344.1	-
electricity generation	581.3	-	-	-581.3	-	-	-
Transformation and Distribution	-116.3	-	-	-	-	-	-116.3
Total Transformation	465.0	-	-344.1	-581.3	-	344.1	-116.3
Kirtipur Municipality	465.0	2.8	40.4	-	54.1	344.1	906.3
Total Demand	465.0	2.8	40.4	-	54.1	344.1	906.3

APPENDIX 3: Sankey Diagram

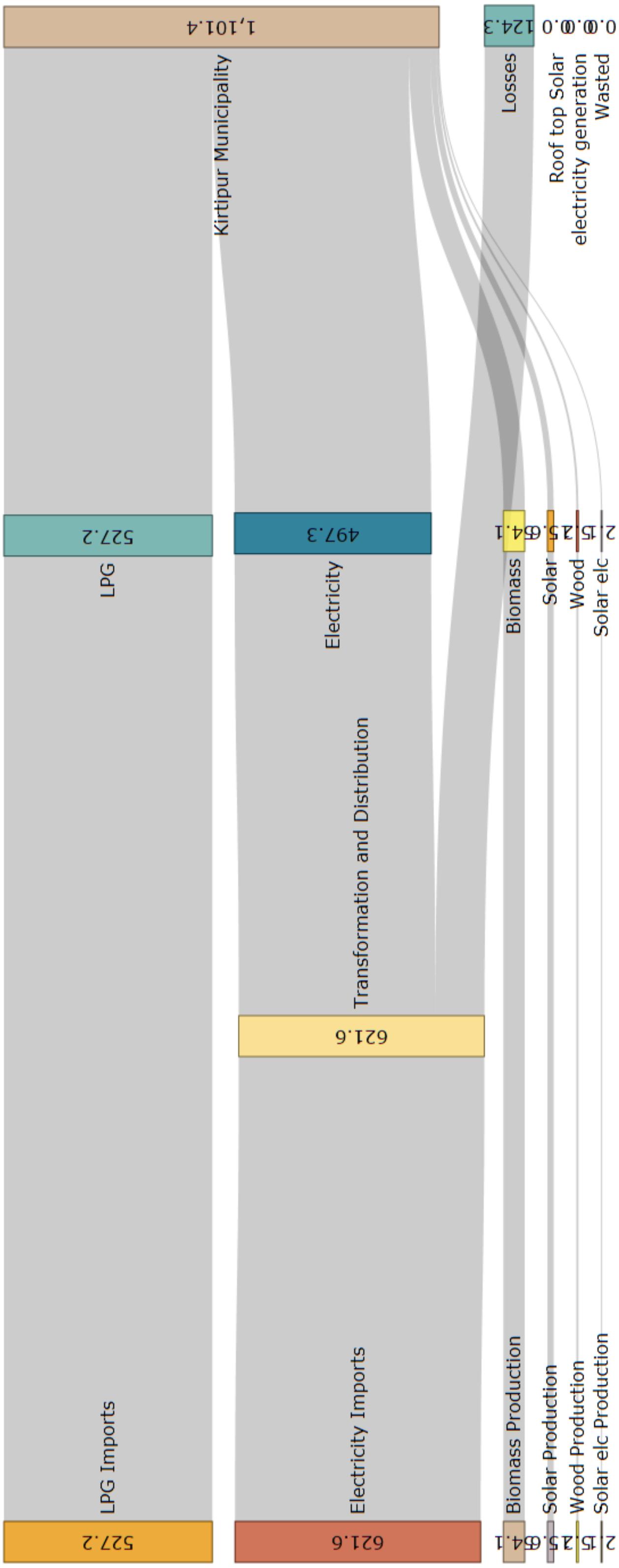
Sankey Diagram: BAU 2018 in TJ



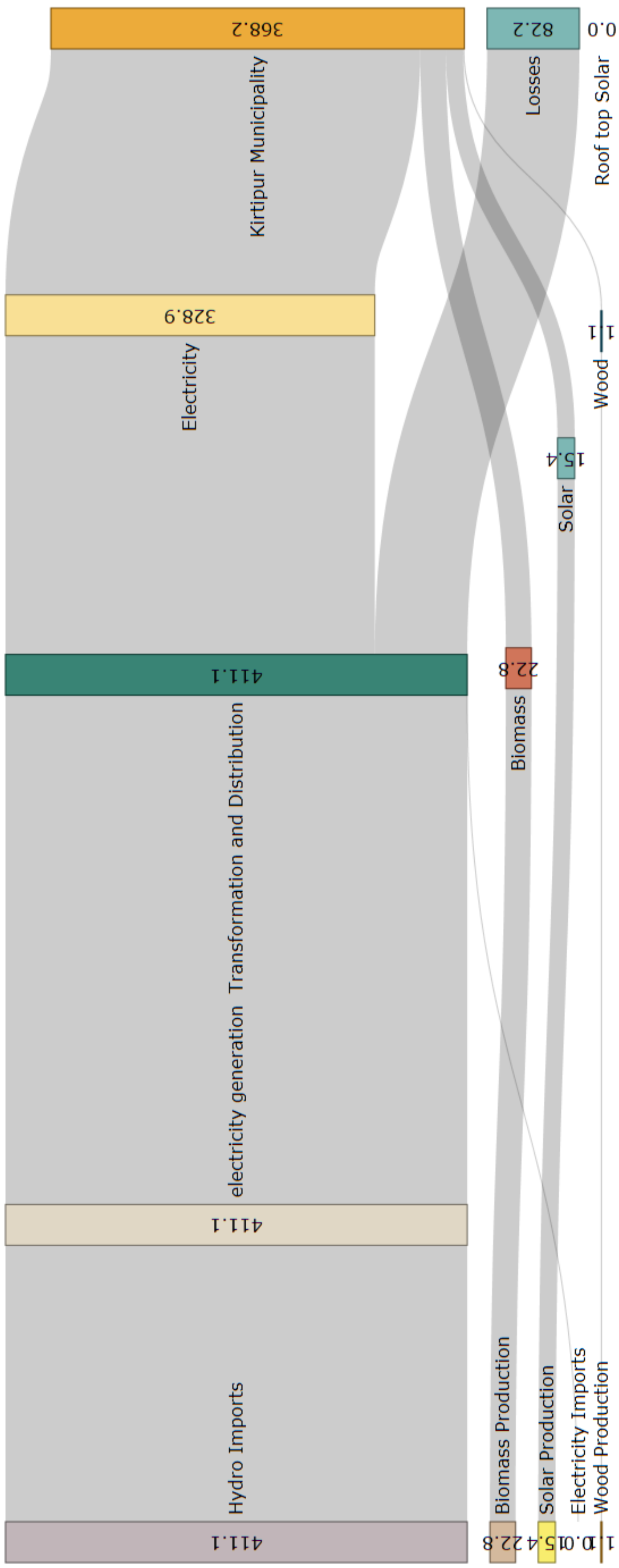
Sankey Diagram: BAU 2030 in TJ



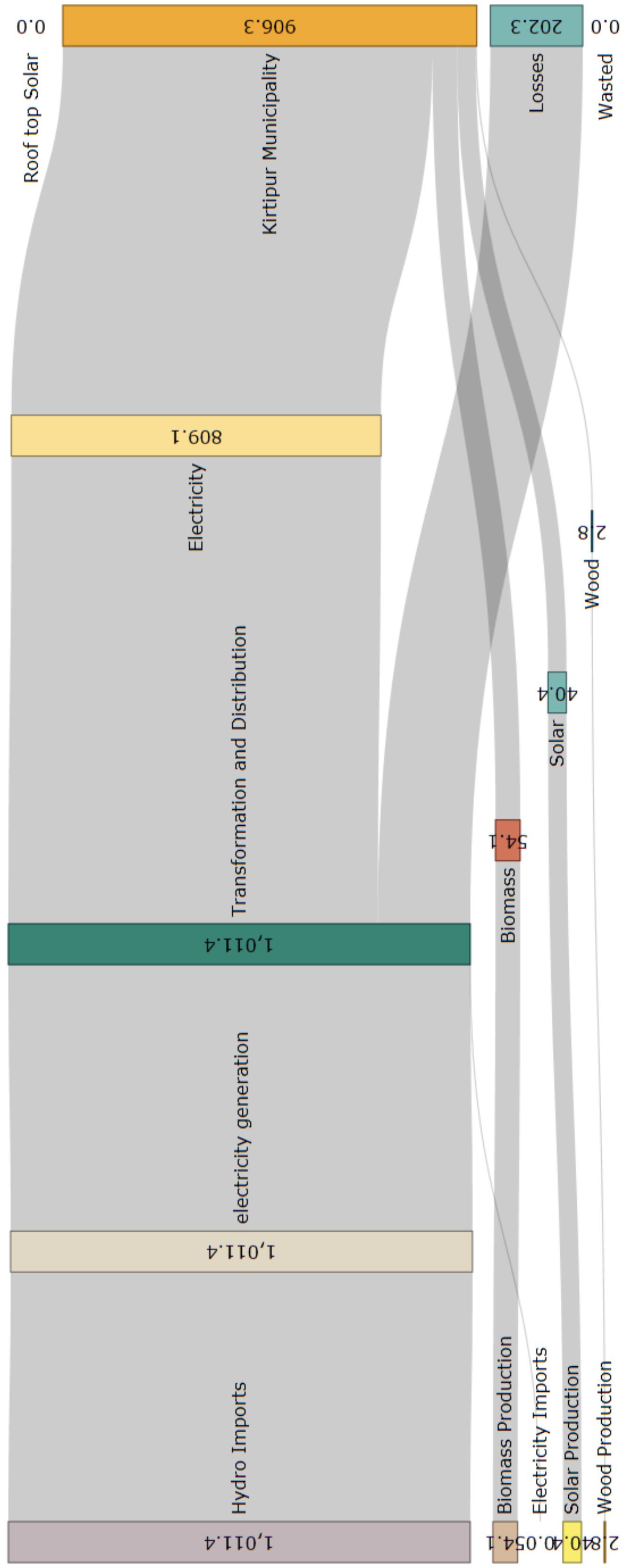
Sankey Diagram: BAU 2050 in TJ



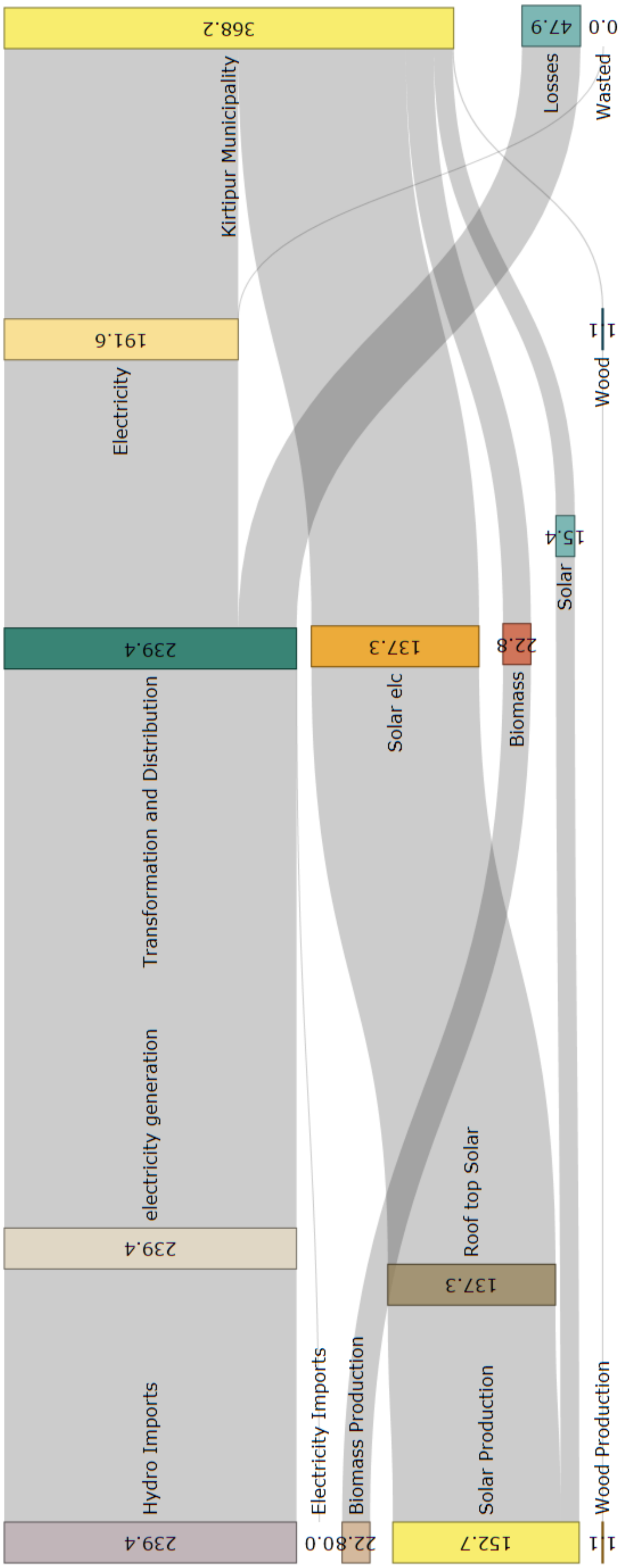
Sankey Diagram: EHE 2030 in TJ



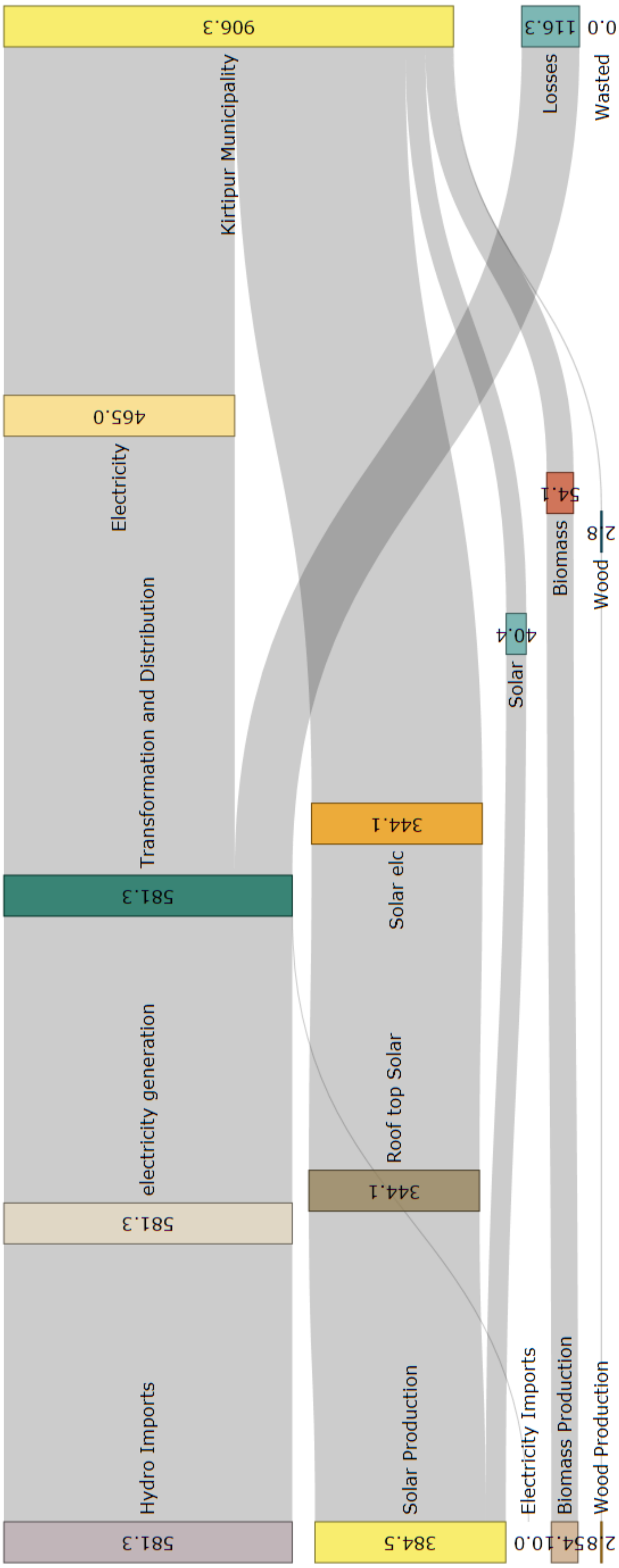
Sankey Diagram: EHE 2050 in TJ



Sankey Diagram: SDG 2030 in TJ



Sankey Diagram: SDG 2050 in TJ



APPENDIX 4: Photos from the Field