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Implementation of Electric Cooking in Madhesh Province to Increase Domestic Electricity Consumption

by

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis report entitled "**The implementation of Induction Cooking in Madhesh Province to Increase Domestic Electricity Consumption**" submitted by **Anil Parajuli** in partial fulfillment of the requirements for the degree for the Master of Science in Energy System Planning and Management.

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ABSTRACT

Electric cooking is one of the best options to reduce the import-based LPG consumption and to increase the domestically generated electricity consumption in Nepal. This research is based on the national target of implementing electric cooking in 25% of households up to 2030. Madhesh Province is chosen for the study as this province has nearly finished electrification. The MATLAB Curve Fitting Toolbox is used for historical data fitting, selection of forecasting models and forecasting.

The distribution of households in Madhesh Province using LPG, electricity and other cooking fuels for their primary means of cooking in 2021 are 28.7%, 0.8% and 70.5% respectively. In the base case scenario, the distribution of households using LPG, electricity and other cooking fuels are found to be 65.2%, 2.7% and 32.2% respectively by 2030 and in the electric cooking implementation case the distribution of households will be 42.83%, 25.00% and 32.2%. The electricity requirement in the base case scenario is found to be increased to 6265 GWh in 2030 from 2229 GWh in 2021. In the electric cooking implementation scenario, the electricity requirement will be 6920 GWh which is about 10.45% higher than the base case scenario. Similarly, the peak demand required in 2030 will be 1192 MW in the base case scenario and 1631 MW in the electric cooking implementation scenario. The maximum households in which electric cooking can be implemented are found to be on nearly 7% as per the distribution feeder and substation loading condition. The saving of LPG replaced by electricity for cooking purposes is calculated approximately 46,175 MT in 2030 and cumulative saving of LPG from 2023 to 2030 is found to be approximately 200,854 MT.

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Anil Parajuli

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LIST OF ABBREVIATIONS

GDP	Gross Domestic Product
GHG	Greenhouse Gas
GoN	Government of Nepal
GWh	Gigawatt Hour
HEP	Hydroelectric Plant
IPP	Independent Power Producer
KW	Kilo Watt
KWh	Kilowatt Hour
LPG	Liquified Petroleum Gas
MW	Mega Watt
NEA	Nepal Electricity Authority
NOC	Nepal Oil Corporation
NSO	National Statistics Office
PJ	Peta Joule
TJ	Tera Joule
WECS	Water Energy and Commission Secretariat

CHAPTER ONE: INTRODUCTION

1.1 Background

Energy is very essential for a human kind in every stage of their life and it plays a crucial role in promoting the welfare, economic growth, and infrastructure development of a nation. With the increase in the population, the utilization and exhaustion of the world's fossil fuel storage is going rapidly as it can be converted to another energy source easily. Which in turn the usage of fossil fuels will also generate millions of tons of carbon dioxide and various greenhouse gasses. To fulfill the increasing demand of energy with the consideration of clean environmental goals, different kinds of renewable energy resources can be utilized.

In most of the developing countries, more than half of the energy consumed in households is used for cooking and reducing the energy consumption in cooking can have a significant impact on the total energy system (Pokharel, 2004). In the context of Nepal, 63.2% of total energy is consumed in the household sector and 84.9% of fuel source for the residential sector comes with fuelwood (WECS, 2022). In spite of having huge potential of electricity and renewable energy resources, utilization of those resources is in the beginning stage.

Electricity is one of the primary demanded forms of energy, not only for lighting and industrial load but also in the other applications like cooking and transportation due to having many benefits including easy transformation and transmission. In Nepal, electricity generation is dominated by the hydropower plants (NEA, 2022) which are generally generated in the remote area and transmitted via the transmission line to the substation located in the consumption area from which the distribution network will distribute the electricity to the consumers. In recent years many hydropower plants from the government sector as well as from the private sector are being developed. The power exchange to India established electricity as a commodity and made investors motivated to invest in the hydro sector. Along with the export, we should also think about the increase in the domestic consumption of electricity as well.

In Nepal, electric cooking can be taken as the main factor to increase the domestic electricity demand. It will result in reducing the dependency on the imported fossil fuels and many other environmental benefits. The different plans and policies formulated by the Nepal government to promote clean cooking technologies and excess availability of electricity on the national grid are the positive points for shifting the cooking technology from petroleum to electricity (Division, 2021). Among the other electric cooking technologies, induction cooking is considered one of the efficient cooking technologies in which up to 90% of the energy consumed is transferred to the food compared to 40% for gas (Sweeney, Dols, Fortenbery, & Sharp, 2014). Due to having various benefits including higher efficiency; the shifting of traditional cooking technology towards electric cooking technology may increase in the future in alignment with various national policies and strategies. To increase and promote the electric cooking technologies, Nepal has fixed the target to use electric cookers as the primary means of cooking in 25% of households by 2030 (GoN, 2020).

The increase in domestic demand by the usage of electric cooking may arise problems on loading on the distribution network and system demand. The cooking habits will play a major role in the peak demand. Also, the generation adequacy in future should be considered.

Madhesh Province has been selected for the study. This province's all local bodies are fully electrified (NEA, 2021) and for the implementation of electric cooking no extra infrastructure is needed for a few years. This research focuses on the forecasting of the demand for next ten years by considering the shifting towards the electric cooking technologies and it'll quantify how much electrical energy will be needed with the implementation of electric cooking.

1.2 Problem Statement

The total grid connected power plant's installed capacity is 2185 MW including IPPs (NEA, 2022). To accelerate the electricity generation, the Government of Nepal has (GoN) set the target to generate 14000 MW of clean energy 14000 MW in which 5-10% will be from mini and micro hydro power, solar and bio-energy by 2030 (GoN, 2020). We should also increase the electricity consumption with the increase in the generation and increased national consumption of energy will have a positive effect on GDP (Campo & Sarmiento, 2013). After starting the production from Upper Tamakoshi HEP (456 MW) in September 2021, NEA declared that the country has surplus electricity production. Also, 3223 MW of hydropower projects are in under construction phase and projects at different phases of development are of capacity 1504

MW. Nepal has exported 494 GWh of electricity to India in F/Y 2021/22 and import was 1543 GWh. So, Nepal is deficit of about 1050 GWh of electricity in F/Y 2021/22. After the operation of projects that are now under construction, the electricity generation will exceed our domestic demand.

The world is now focusing on the usage of clean forms of energy to reduce the GHG emission and due to the fact that limited storage of fossil fuels is getting reduced day to day. In the context of Nepal, where there is no proven fossil fuel storage and dependent upon the import; should reduce the fossil fuel consumption to reduce the trade deficit, to use the cleaner form of energy and to utilize the hydropower potential. Fossil fuel import from India is in a sustained rising trend which is causing about Rs. 250 billion cash outflows (IOE, KU, NEF, & NF, 2022). Since hydro-electricity is one of our main sources of electrical energy; we should focus on the consumption of this energy as our hydropower potential is still in the beginning stage. In the rainy season, the hydropower plant can be operated in nearly full capacity and there is a spill of energy if energy is not exported.

The rising petroleum import and excess of electricity might be balanced by implementing electric cooking. Electric cooking might replace some portion of LPG consumption along with an increase in electricity consumption.

This study is focused on Madhesh Province to increase electricity consumption via electric cooking. Madhesh Province has been chosen because this province has nearly finished electrification (NEA, 2021) and one of the provinces having higher households and population.

1.3 Objective

1.3.1 Main Objective

The main objective of this research is to find the year wise electricity demand for up to 2030 by implementing electric cooking in Madhesh Province.

1.3.2 Specific Objectives

The specific objectives to achieve the main objective are as follows:

- To analyze the past electrical energy demand in Madhesh Province and predict the demand up to year 2030 in base case scenario and in implementation of electric cooking.
- To determine the peak load demand in base case scenario and by electric cooking implementation scenario for Madhesh Province up to year 2030.
- To analyze the requirement of LPG up to 2030 and saving of LPG by the implementation of electric cooking.
- To find the optimum implementation level of electric cooking in existing infrastructure in Madhesh Province.

1.4 Research Gap

The gap for which this research work is carried out are listed below:

- This research is based on the national target of implementing electric cooking. Previous researches were focused on the implementation on feeder level and analyzed the impact on feeders.
- Saving of LPG fuel consumption were not a priority in most of the researches.

1.5 Limitations

There are the following limitations of this study:

- Induction cooker is considered as the electric cooking technology for the analysis.
- The distribution transformers are assumed to have enough capacity to implement the electric cooking in Madhesh Province. The power quality and reliability issues are not covered by this study.
- The shifting of cooking fuel is considered as traditional to LPG to Electricity.
- Only LPG and Electricity as cooking fuel are considered for the analysis and comparison.
- The quantity of LPG is calculated according to the LPG requirement in the cooking sector as per (WECS, 2021) and future values are projected on the basis of 2019 values.

- The optimum penetration level is calculated from maximum feeder loading and maximum substation loading. The conductors used in feeders are taken from (DCSD, 2022) and the highest size of conductor is used for analysis.
- The peak demand is calculated from average annual electricity demand (GWh) and Load Factor and maximum 50% of total Induction stoves connected are assumed to be in operation at a time.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview of Madhesh Province

2.1.1 General Overview

Madhesh Province, which has an area of 9 661 km^2, lies in the south-eastern part of Nepal and is one of the seven provinces established by the Constitution of Nepal that was adopted in September 2015. It borders Koshi Province to the East, Bagmati Province to the North, and India to the South. This Province has eight districts. All the districts in this province are linked with the Indian Territory. The capital city of Madhesh Province is Janakpur. The detailed map of Madhesh Province is shown in Figure 2. 1.

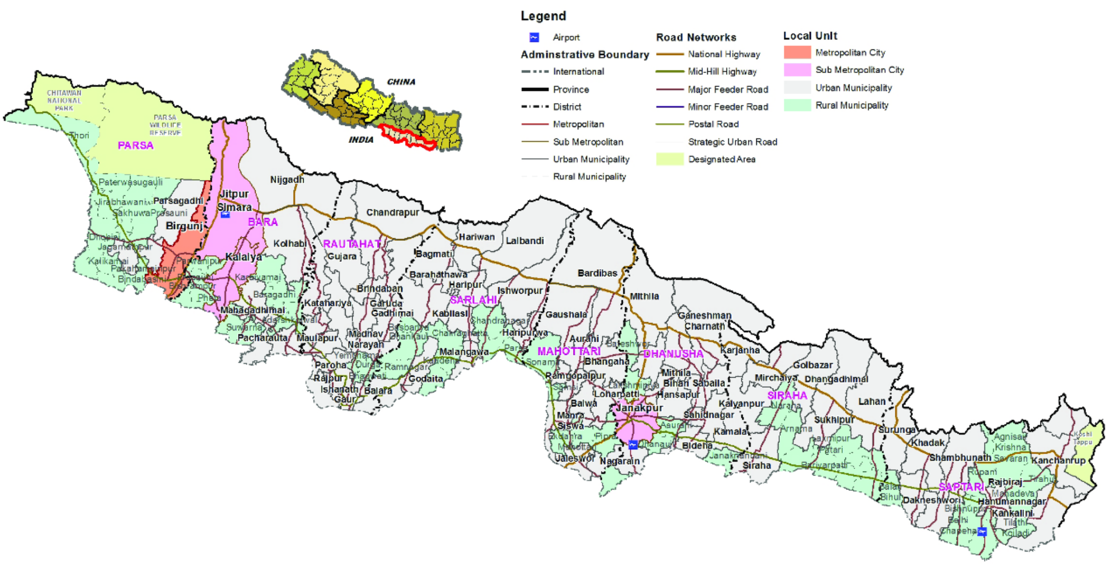

Figure 2. 1: Detailed Map of Madhesh Province (Wikimedia, 2023)

2.1.2 Population and Household Status

According to the census data of 2021, the population of Madhesh Province is 6,114,600 with 73% of the population living in urban municipalities. The average annual population growth rate of this Province is 1.19%. The total number of households are 1,156,715 with average household size of 5.29 person per household. The population density is 633 in which highest population density is at Dhanusha District, 735 and lowest at Parsa District, 484 (NSO, 2023). The details of population in Madhesh Province are summarized in Table 2.1.

Table 2. 1: Population and Household Data of Madhesh Province (NSO, 2021)

District Name	Population	Households	Population Density	Average HH Size
Parsa	654471	113080	484	5.79
Bara	763134	131240	641	5.81
Rautahat	813573	137032	723	5.94
Sarlahi	862470	164893	685	5.23
Mahottari	706994	137902	706	5.13
Dhanusha	867747	177143	735	4.9
Siraha	739953	148571	623	4.98
Saptari	706255	146854	518	4.81
Total	**6,114,597**	**11,56,715**	**633**	**5.29**

2.2 Total Energy Consumption Status

According to Nepal Energy Sector Synopsis Report 2021/22, 63 PJ of energy was consumed in Madhesh Province in 2019 which is about 10% of total national energy consumption. The energy consumed by the residential sector was about 62% of total energy. And the main source of energy in the residential sector is dominated by fuelwood which has a share of about 53% (WECS, 2022). The share of different energy resources by different sectors in Madhesh Province are illustrated in Figure 2. 2, Figure 2. 3 and Figure 2. 4.

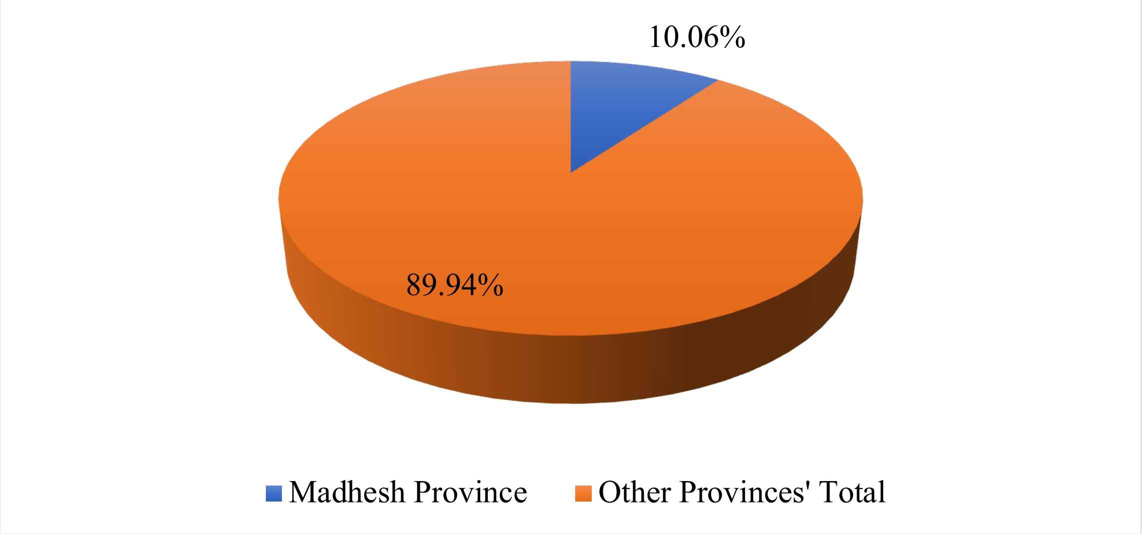

Figure 2. 2: Total Energy Consumption Status in Madhesh Province, 2019

Figure 2. 2 shows that about 10% of total energy consumption in Nepal was consumed in Madhesh Province in the year 2019.

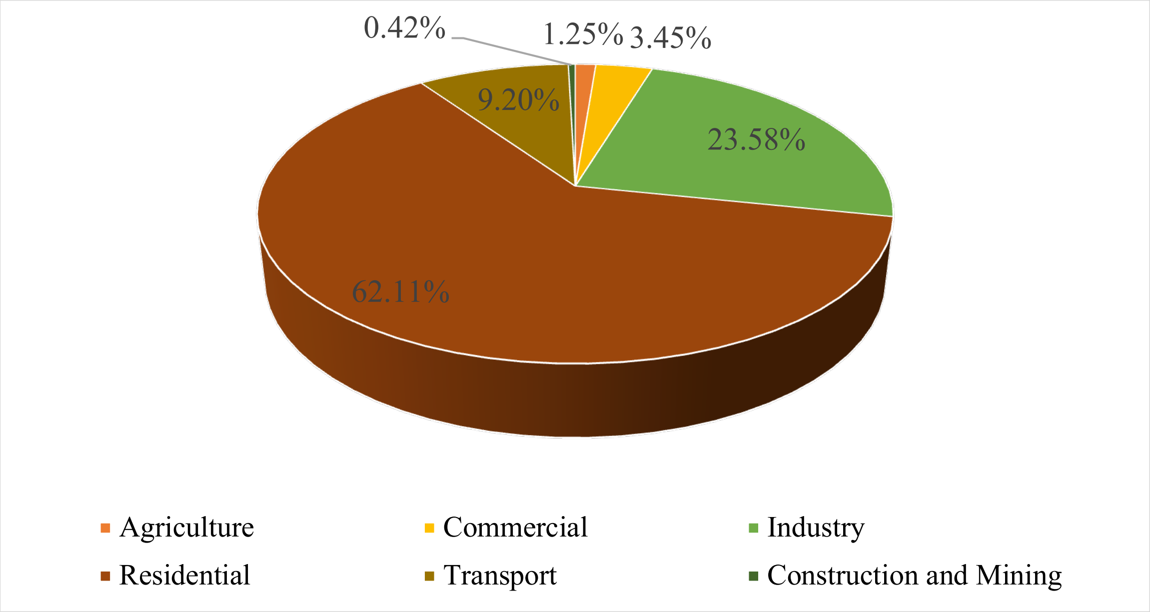

Figure 2. 3: Energy Consumption by Different Sectors in 2019

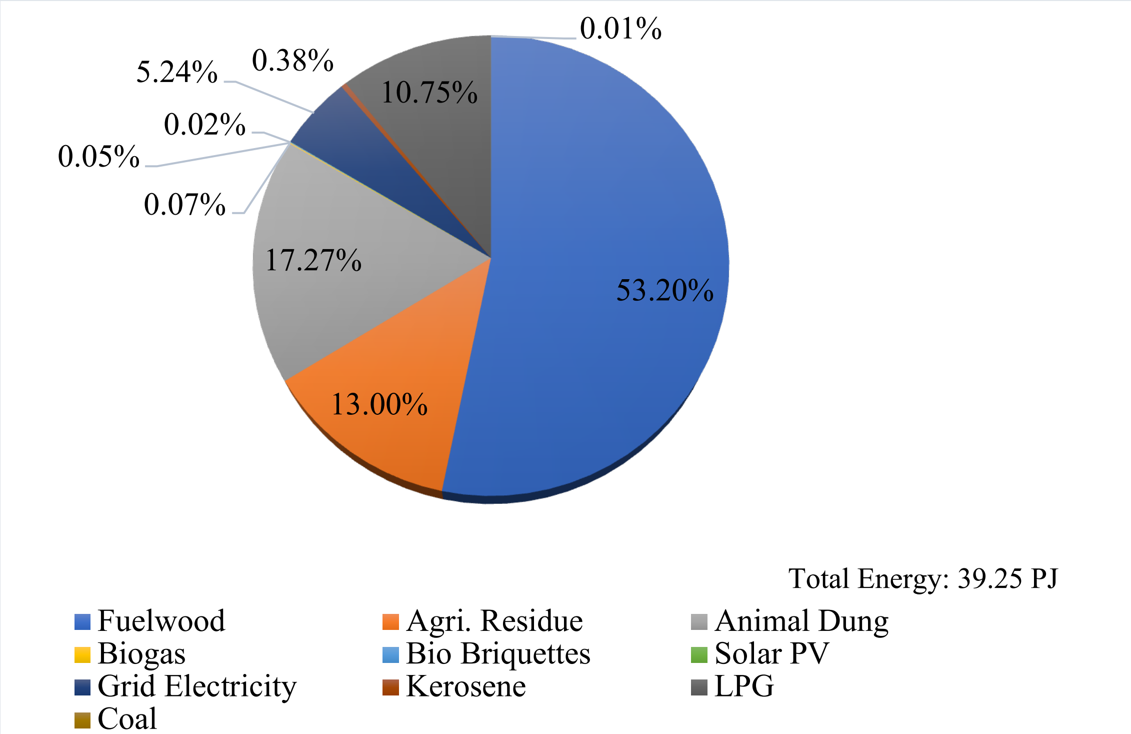

Figure 2. 4: Energy Consumption Status of Residential Sector, 2019

2.2.1 Energy used in Cooking:

In Madhesh Province, energy consumption in the residential sector is 39.25 PJ in 2019 in which 33.62 PJ (86%) of energy is used for cooking purposes (WECS, 2021). Also, 5.83% of total energy is used for the preparation of animal feed. The share of end-use of energy in the residential sector is illustrated in Figure 2. 5.

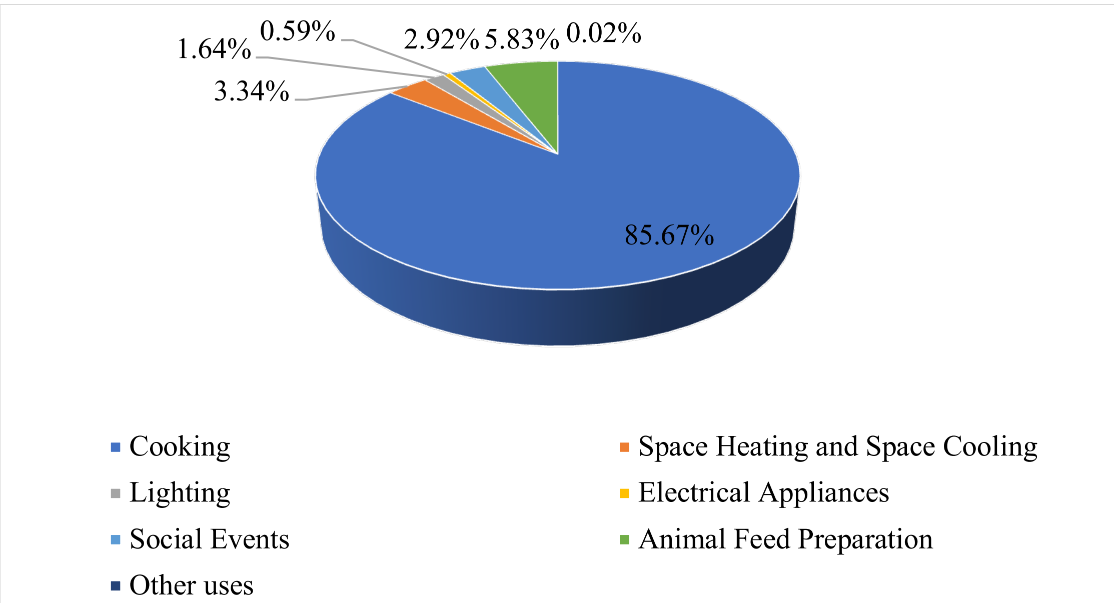

Figure 2. 5: End use of Energy (WECS, 2021)

For the cooking purposes, 60% (20 PJ) of total energy used came from wood (fuelwood/firewood). Also, Agriculture residue and animal waste are the major contributors in cooking fuel resources followed by LPG (8.46%). The use of electricity for cooking purposes was found to be just 74 TJ in 2019. The figure 6 shows the energy mix in cooking use in Madhesh Province for the year 2019.

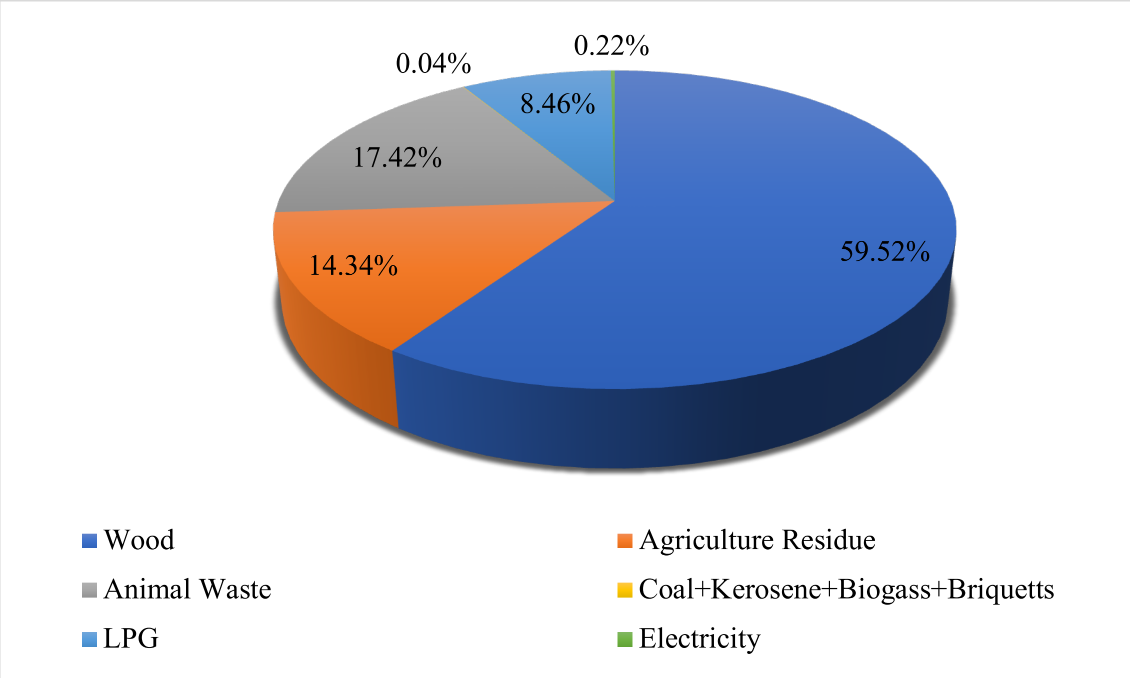

Figure 2. 6: Share of Cooking Fuel in residential sector

2.2.2 Increasing trend of using LPG

The National Population and Housing Census of 2011 shows that the share of households using Fuelwood/Firewood as a main source of fuel for cooking purposes is 64% followed by LPG as 21.03% (CBS, 2011). The annual households survey of Nepal, 2016/17 shows that 52.4% of households use firewood as the main fuel for cooking followed by LPG as 33.1% in F/Y 2016-17 (CBS, 2018).

Share of households using LPG The share of households using LPG as a cooking fuel is increased to 34.90% in 2018 (Pinto, Yoo, Portale, & Rysankova, 2019). The National Population and Housing Census 2021 shows that the share of households using LPG for cooking has increased to 44.3% (NSO, 2021). Figure 2. 7 shows the share of households using different cooking fuels in 2011 to 2021. From Figure 2. 7 we can see that there is rising trend of households using LPG while the use of firewood/fuelwood and other fuels are reducing from past years.

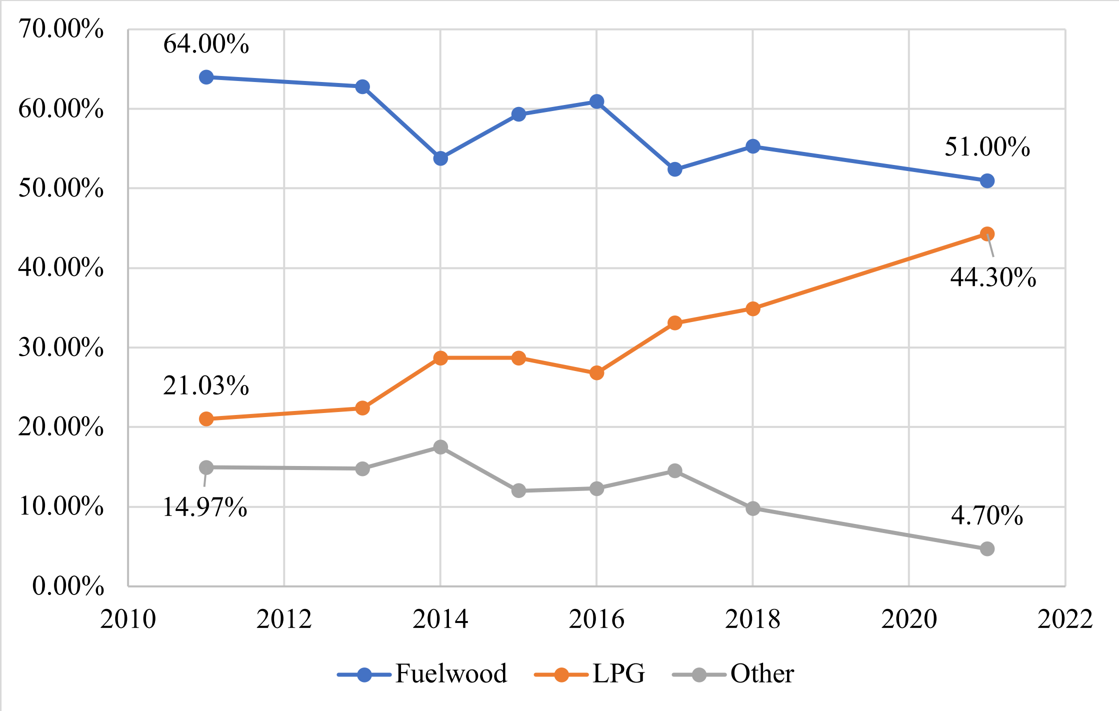

Figure 2. 7: Share of Households using different fuels for cooking for Nepal (CBS, 2011) (CBS, 2018)

Also, from the sales data of LPG in Nepal, the rising trend of usage of LPG in the household sector can be visualized. Figure 2. 8 shows the trend of LPG sales in Nepal from year 2011 to year 2022.

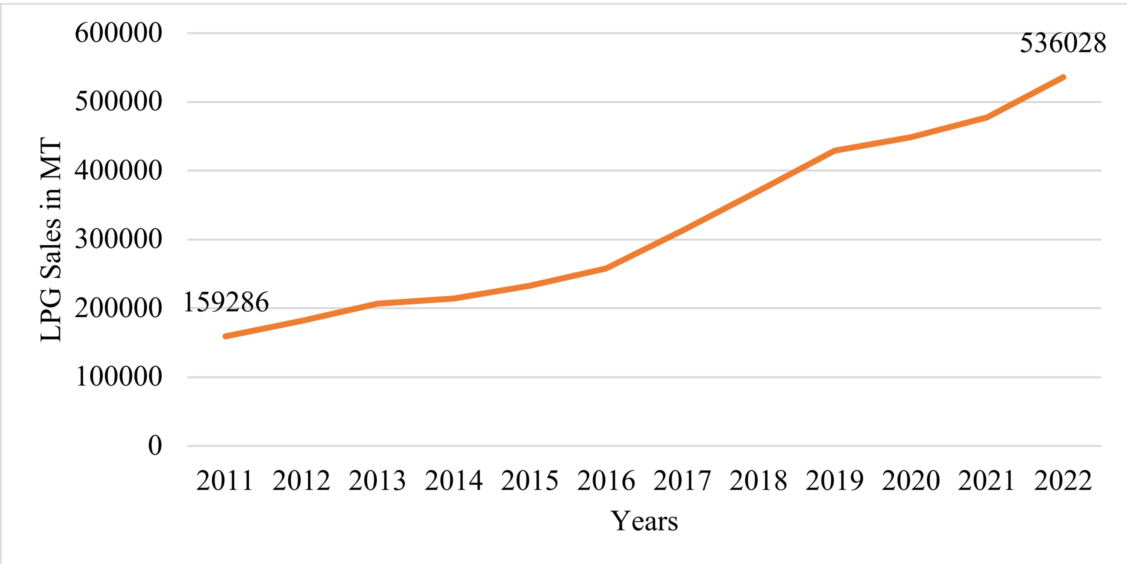

Figure 2. 8: LPG Sales of Nepal (NOC, 2023)

In the case of Madhesh Province, according to the census data of 2021, 58.6% of total households are using the main source of energy for cooking purposes as

Firewood/Wood which is an increase from 52.1% in 2011 (NSO, 2023). The share of households using LPG in the cooking fuel accounts for 28.7% in 2021. Figure 2. 9 shows that the households using LPG as main source of fuel for cooking has largely increased and households using cow dung has decreased in the past 10 years. The use of electricity as the main source of fuel for cooking purposes is found to be only in 0.8% of households (NSO, 2023).

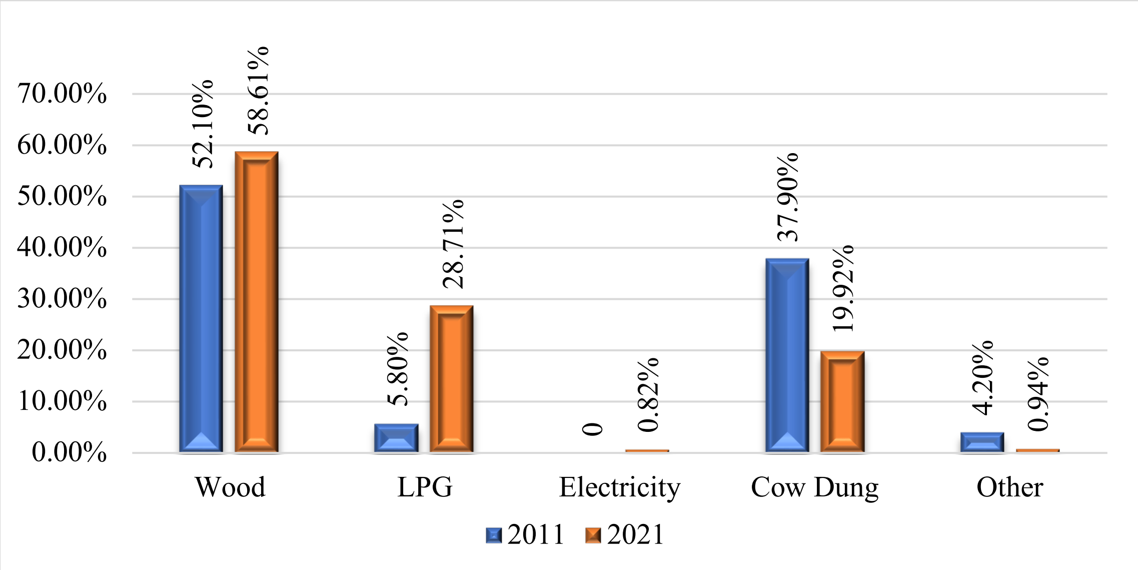

Figure 2. 9: Comparison of share of Households using different fuels for cooking in 2011 and 2021 (NSO, 2021)

Figure 2. 9 shows that the majority of households in Madhesh Province are still using traditional fuel as a main fuel for cooking purposes as a national trend and followed by LPG. We can see that the use of LPG is increasing so rapidly as many households are shifting the cooking fuels from traditional to commercial. The national data reveals that the share of households using LPG will increase from 21.03% in 2011 to 44.3% in 2021. Similarly, the share of households using LPG in Madhesh Province has increased from 5.8% in 2011 to 28.7% in 2021. Since petroleum products are being imported from another country, rapid increase in use of petroleum products will increase dependency on import as well as the trade deficit. We can decrease the share of Fuelwood/wood and LPG as the main source for cooking by implementing the electric cooking technology in Madhesh Province.

The majority of households are using traditional fuels for cooking. The share of LPG as the cooking fuel is 28.71% in 2021. By taking LPG and Electricity as the commercial fuels in the cooking sector, the share of commercial fuels is 29.59% in 2021 which has increased from 5.8% in 2011 (NSO, 2023).

Figure 2.10 shows that the numbers of households using traditional cooking fuels are decreasing and use of commercial fuels are increasing. We can see that the share of households using LPG as a cooking fuel is increasing rapidly and households using electricity have only grown to less than 1 % up to 2021. In the past ten years, households using LPG rose by 2.3% per year on average. And usage of electricity as main fuel for cooking has just risen by 0.88% in the last ten years (NSO, 2023).

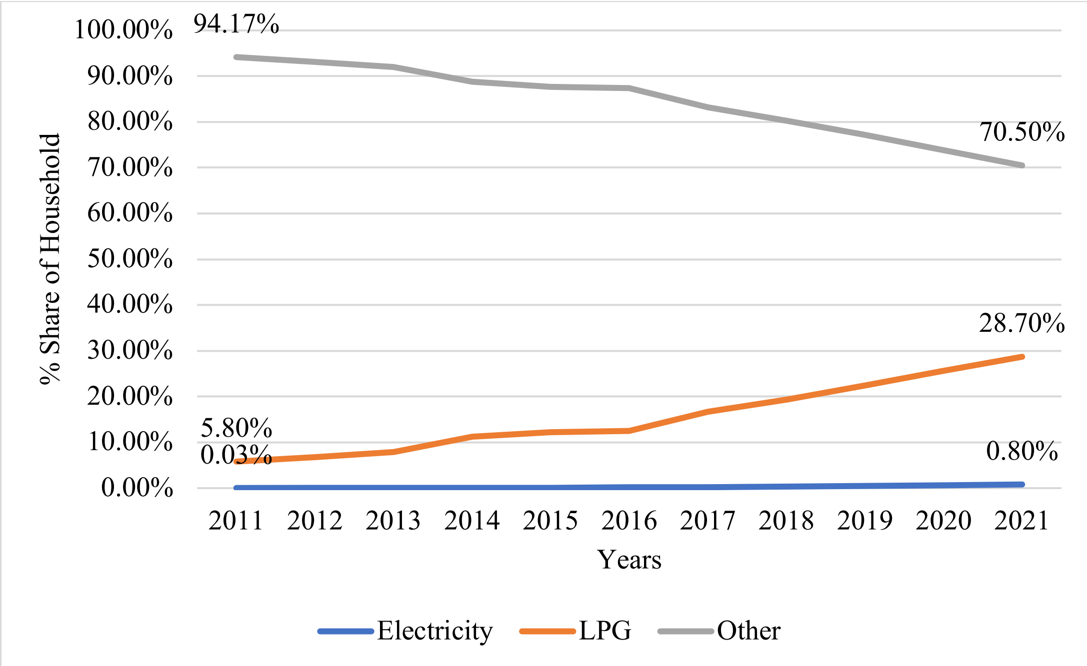

Figure 2. 10: Share of household using different fuels for cooking from 2011 to 2021 in Madhesh Province (CBS, 2018) (CBS, 2011) (NSO, 2023) (Pinto, Yoo, Portale, & Rysankova, 2019)

The share of households using other cooking fuels (firewood/fuelwood, cow dung, agriculture residue etc.) are getting reduced in years; which is reduced from 94% in 2011 to 70.5% in 2021.

The Figure 2.11 shows the share of mainly used cooking fuels in Madhesh Province in 2021.

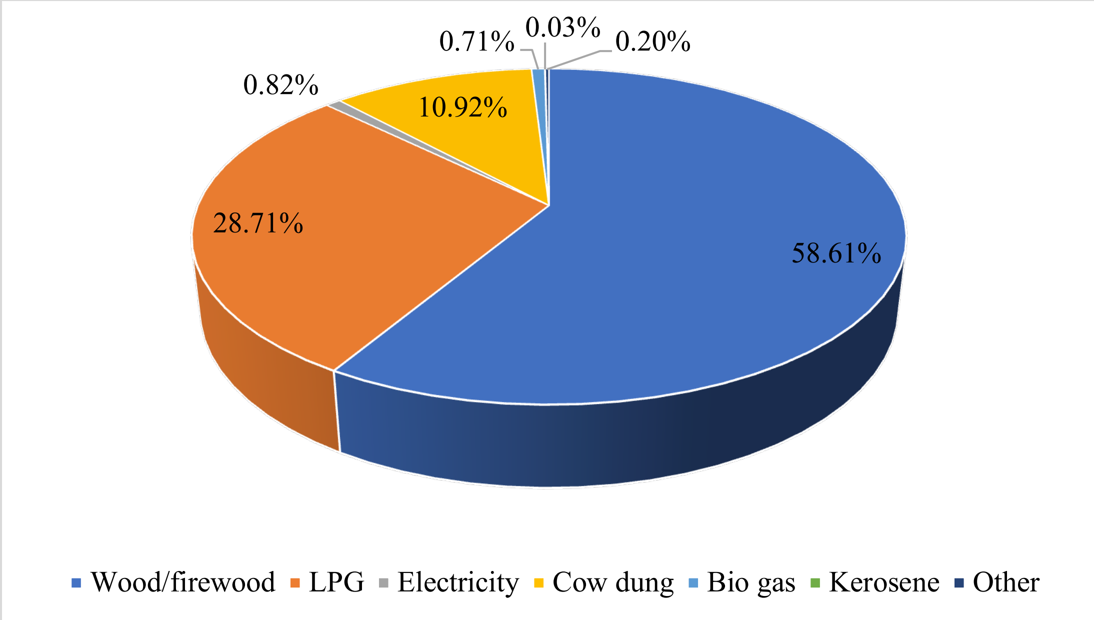

Figure 2. 11: Share of Households using main fuel for cooking, 2021 (NSO, 2021)

The total energy consumption was 63 PJ in 2019 in Madhesh Province. The share of LPG on the total energy consumption was 7.34%. On the other hand, the total energy consumption was 589 PJ and the share of LPG on total energy consumption was 3.33% for the same year in Nepal (WECS, 2021) (WECS, 2022). The share of LPG in total consumption in Madhesh Province is found to be higher than national data. The share of LPG in total energy used in the residential sector is 10.75% (4.22 PJ). Also, as per the Energy Synopsis Report (2022), 23.66% of total LPG imported was consumed in Madhesh Province in the year 2019.

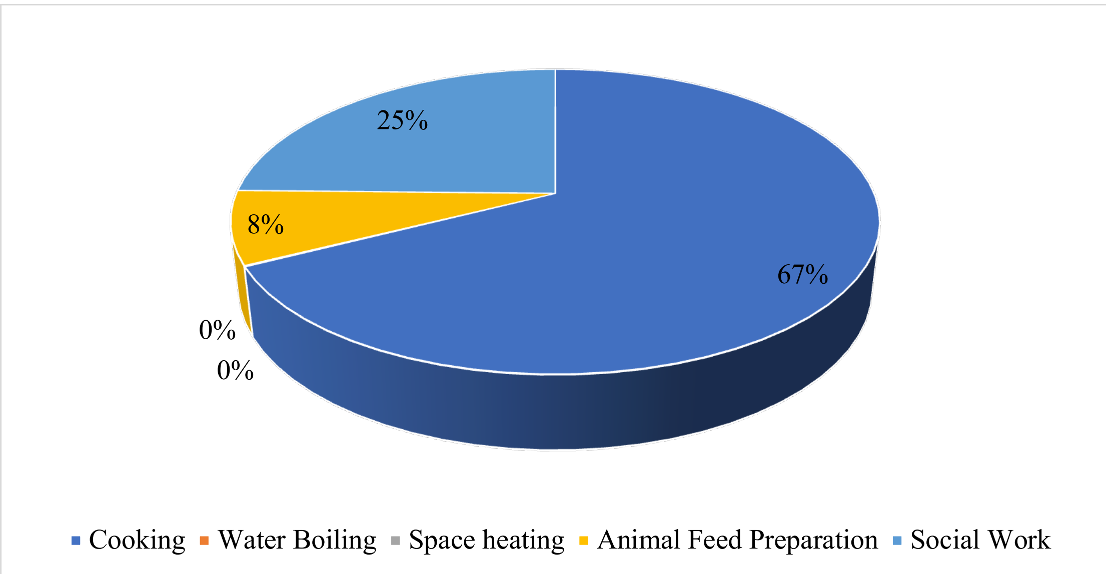

Figure 2. 12: LPG usage in a household

Figure 2.12 shows that a major portion of LPG consumption is for cooking purposes (67%) followed by social work and animal feed preparation.

The use of LPG used in Madhesh Province for the year 2019 can be described via Figure 2.13.

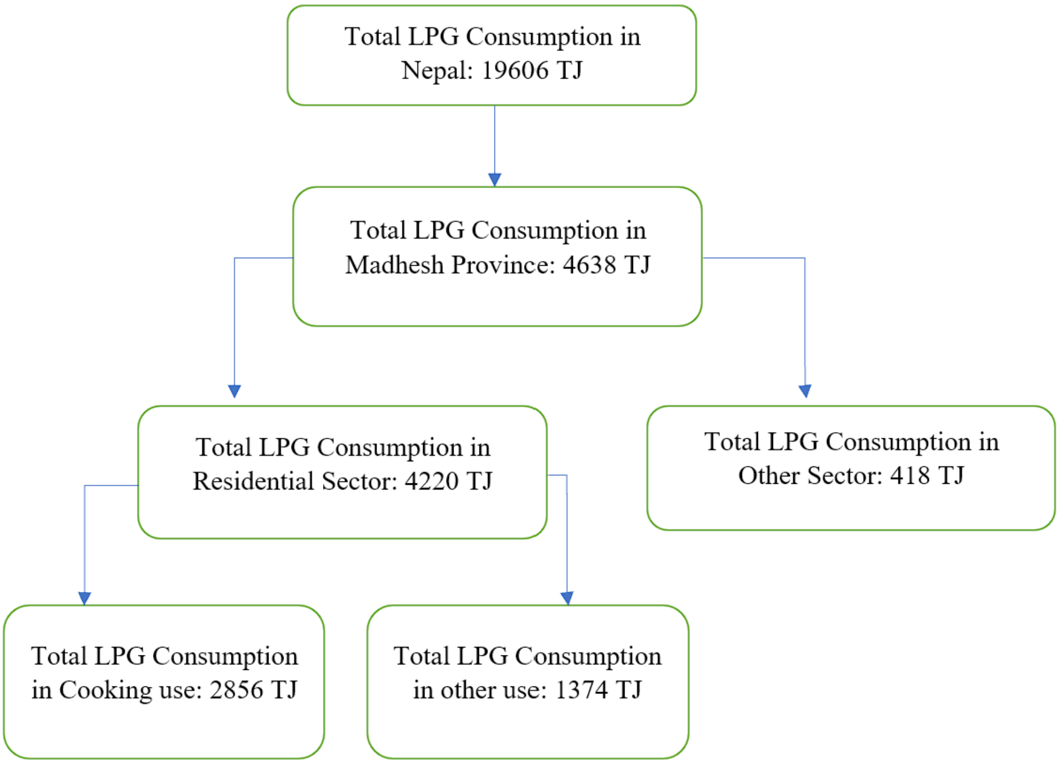

Figure 2. 13: LPG used in different purposes in Madhesh Province (2019) (WECS, 2021) (NOC, 2023)

The total LPG import of Nepal for the year 2019 was 429609 MT (NOC, 2023). For the year 2019, the total LPG consumption as per (WECS, 2022) was 19606 TJ. Also, the total LPG consumption in Madhesh Province was 4638 TJ in the same year which is 23.66% of total LPG consumption of Nepal. As per (WECS, 2021), the LPG usage in the residential sector was 4220 TJ and the other sector was 418 TJ. In the residential sector, LPG is used in cooking, water boiling, animal feed preparation, space heating and social works. The share of LPG in cooking use is 2856 TJ. From this usage pattern, we can say that 61.58% of LPG used in Madhesh Province is used for cooking purposes only. If we add water boiling and space heating with cooking, the total LPG used was found to be 2851 TJ that can be replaced by electricity.

Cookstove and Cooking Fuel Staking

While most of the households in Nepal use only one type of stove, there are some households that use two or more different types at the same time. This practice is referred to as stove stacking (Pinto, Yoo, Portale, & Rysankova, 2019). According to (Pinto, Yoo, Portale, & Rysankova, 2019), 82.9% of total households use a single stove and 16.4% of households use two cook stoves. Also, 80.7% of total households use single cooking fuels whereas 15.6% use two fuels and 3.7% use more than two cooking fuels. 11.4% of households were found to be using LPG with other cooking fuels.

2.2.2 Energy used in Lighting

For lighting purposes, almost all households have access to electricity, the main source of lighting is electricity. 97.9% of the total households are using electricity as the main source of lighting which was 59.7% in 2011 as per the census data of 2011 (NSO, 2023). The report published by Nepal Electricity Authority shows that 99.66% of households have access to electricity which is highest among other provinces (NEA, 2021).

2.3 Electricity Supply and Demand Status

Electricity supply in Madhesh Province is provided mainly by Nepal Electricity Authority (NEA) through the national grid. In the distribution sector, NEA has one provincial office at Janakpur and other 23 distribution centers in different districts. The distribution of electricity is carried out by 9 grid substations (132 kV and 66 kV) and 26 primary distribution substations having total capacity of 689 MVA (33 kV and 11 kV Distribution system). This province has 880 KM of 33 kV line and 6,504 KM of 11 kV line with 6,330 Nos. of distribution transformers (DCSD, 2022). The total cumulative loading of the 11 kV feeder in 2022 is 470 MVA.

Figure 2. 14 shows the loading of substations in different fiscal years. The loading of substations in different fiscal years shows that the demand is increasing every year. The demand is minimum Kartik to Falgun and maximum Chaitra to Asoj.

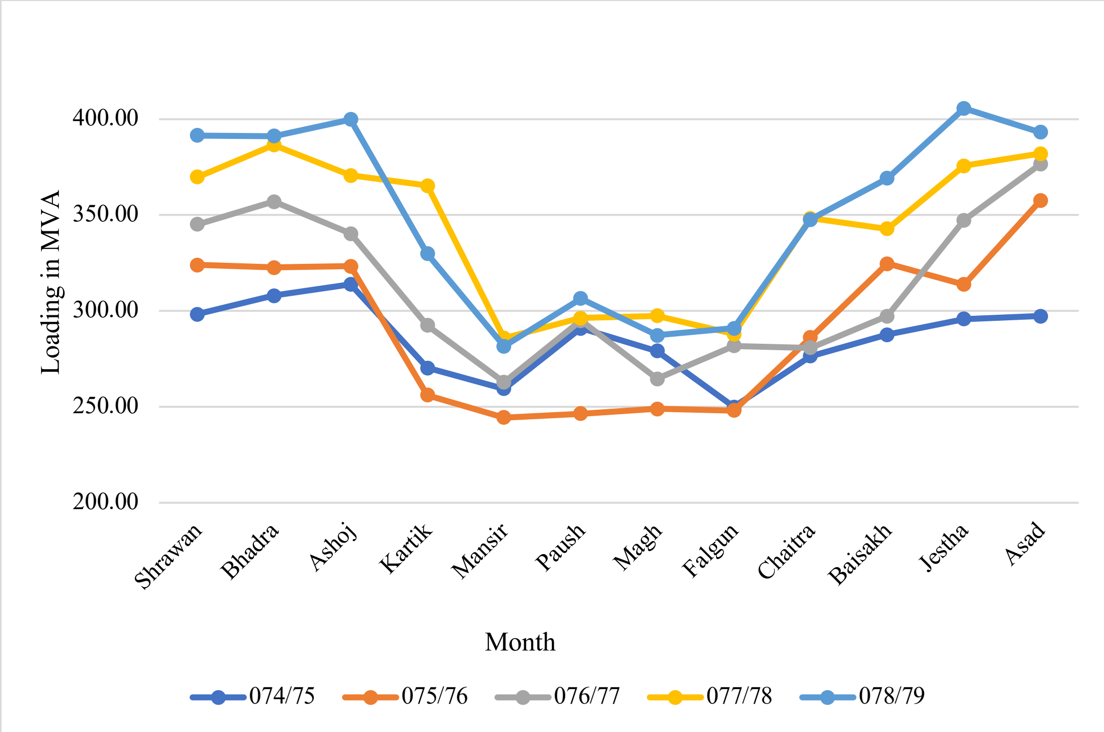

Figure 2. 14: Maximum Loading of Substations of Madhesh Province in Different Fiscal Years

2.3.1 Electricity Consumption and No. of Consumers:

The total number of consumers are 983,023 in which 90.25% are domestic consumers as of up to Asar, 2079. Total electricity consumption for F/Y 2078/79 in Madhesh Province is 2229.23 GWh including distribution loss of 14.17%. Despite having large domestic consumers, the electricity consumption of domestic consumers is about 31% of total electricity consumption and revenue from domestic consumers is only 28.72% of total revenue (NEA, 2022). The domestic sector can be used to increase the electricity consumption as there are a large number of domestic consumers.

The share of different consumer categories and their electricity consumption are shown in Figure 2. 15 and Figure 2. 16.

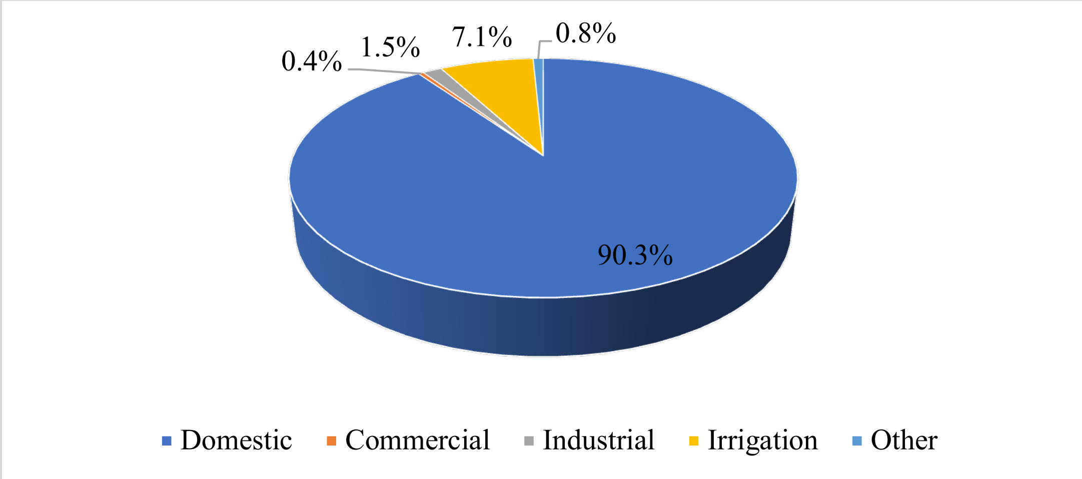

Figure 2. 15: Consumer Category at Madhesh Province

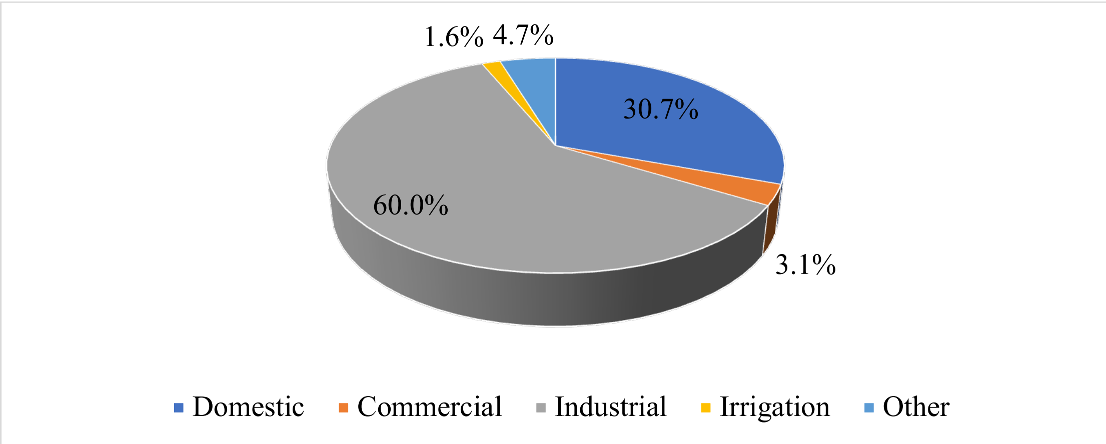

Figure 2. 16: Electricity Consumption by Different Sectors

Figure 2.17 shows the numbers of consumers' growth throughout the past five fiscal years. The number of domestic consumers at F/Y 2074/75 was 643,369 and reached 887,190 in F/Y 2078/79 (NEA, 2021).

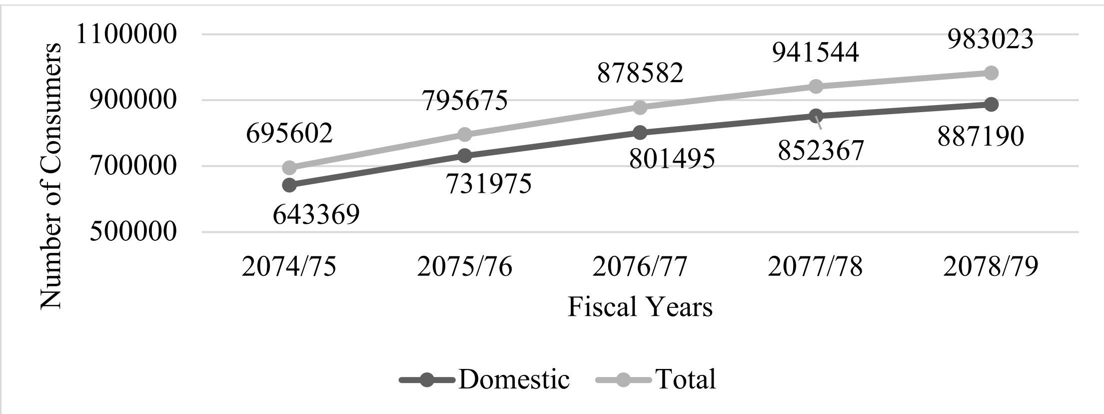

Figure 2. 17: No. of Consumer in Madhesh Province

From Figure 2.17, it is clear that the domestic consumer growth is in line with the growth of total consumers. This is obvious than 90% of consumers are of the domestic category.

From the linearization we can assume the number of total consumers increased by 72,071 per year and number of domestic consumers are increased by 60,803 per year approximately Madhesh Province.

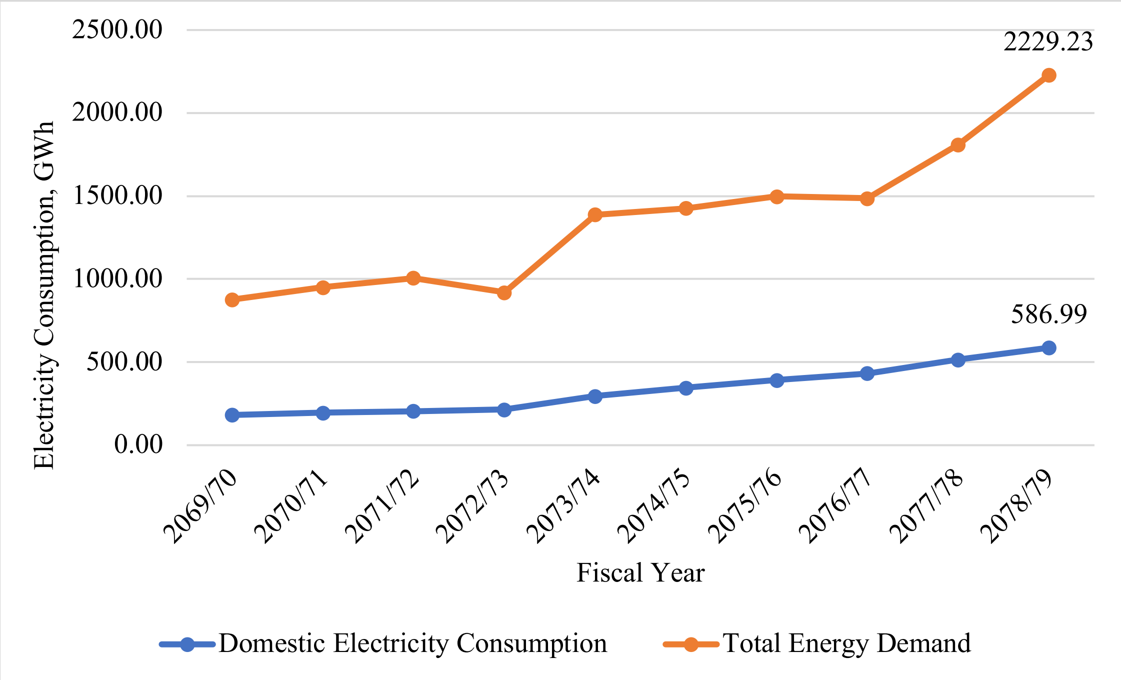

Figure 2. 18: Electricity Consumption Trend in Madhesh Province (NEA, 2021)

From Figure 2. 18, it is seen that the domestic demand is increasing with years. The majority of energy consumption is from the industrial sector as seen from Figure 2. 16. The domestic energy demand in the year F/Y 2069/70 is 182 GWh and the total consumption is 877 GWh including distribution loss. The domestic demand in F/Y 2078/79 is 587 GWh and total demand is 2229 GWh including loss units (NEA, 2021).

2.4 Electric Cooking

Electric cooking refers to the method of preparing food using electrical appliances and devices instead of traditional gas or flame-based methods. It involves the use of electric stoves, cooktops, ovens, grills, and other specialized electric cooking appliances to heat and cook ingredients. With electric cooking, electricity is converted into heat through resistive heating elements or induction technology, providing precise temperature control and even distribution of heat. This approach offers numerous advantages, including faster heat-up times, energy efficiency, safety features like automatic shut-offs, and the ability to cook with consistent heat levels. Electric cooking also eliminates the need for open flames or gas connections, making it suitable for a wide range of settings, including homes, restaurants, and professional kitchens. In our study we considered Induction Cooking as Electric Cooking technology.

2.4.1 Induction Cooking

The basic working mechanism of an induction cooker is illustrated in Figure 2. 19. Induction cooking is a highly efficient and innovative method of preparing food that relies on electromagnetic technology. Unlike traditional cooking methods that generate heat indirectly through burners or heating elements, induction cooktops use electromagnetic fields to directly heat the cookware itself. When an induction-compatible pot or pan is placed on the induction cooktop, a magnetic field is created, which induces an electric current in the cookware, generating heat. This direct transfer of energy results in rapid and precise heating, allowing for faster cooking times and greater control over temperature adjustments.

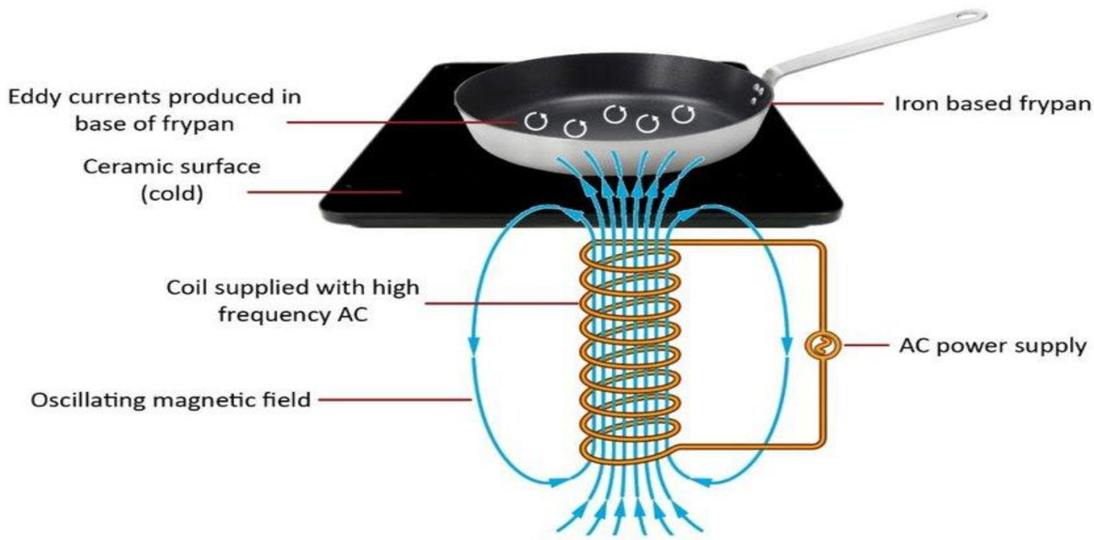

Figure 2. 19: Working Mechanism of Induction Cooker (Tiandho, Indriawati, Putri, & Afriani, 2020)

Advantages and Disadvantages of induction cooking:

One of the significant advantages of induction cooking is its exceptional energy efficiency up to 90%. Since the heat is generated directly in the cookware, there is minimal wasted heat, making it significantly more efficient than gas or electric cooktops. Induction cooktops also offer precise temperature control, allowing for immediate and accurate adjustments to heat levels. Additionally, induction cooking is considered safer compared to other methods, as the cooktop surface itself remains relatively cool during operation, reducing the risk of burns. However, it's important to note that only induction-compatible cookware, typically made of ferrous materials like cast iron or stainless steel, can be used on induction cooktops, as they need to have magnetic properties to work effectively. The induction stoves generate more voltage harmonic distortion during 'ON' mode than standby mode. Current harmonic distortion is higher during induction stoves than in standby mode (RODRÍGUEZ, MARTÍNEZ-GÓMEZ, GUERRÓN, RIOFRIO, & Ricardo, 2019).

2.4.2 Fixed and Operational Costs related to Induction Cooking

Energy saving being the significant advantages for Induction Stoves, the fixed and operating costs are the major things to take care of. Fixed costs are related to the purchase of and installation of those products whereas operating costs are cost for energy. The fixed costs can be divided into induction cooktop and utensils required. The costs for the induction stove having one cook pot capacity can be averaged to about Rs. 3700 with a capacity up to 2000W having user rating higher than four stars in the price range of Rs. 3000 to Rs. 5000 and warranty of one year (Daraz, 2023). The cost for the induction utensils can be averaged to Rs. 3800 (Daraz, 2023). Also, the cost for an induction stove starts from around NRs. 12000 (Daraz, 2023). NEA will take no charge for the capacity upgradation of consumers from 5 A to 15 A, so only cost for 15 MCB (Double pole) Rs. 645 (Committee, 2022) as per the district rate of Kathmandu (the district rate for double pole MCB is not included in the rate list of districts, Madhesh Province) for the fiscal year 2079/80 is considered for the fixed cost. Hence total fix cost can be taken as Rs. 8,045. The fixed cost using two burner induction stove is NRs. 18,345 including utensils.

In case of operation cost, we can take 2.74 hours for the total cooking time in a day (ENERGIA, 2021) by considering that all meals will be prepared on an induction cooktop. By using a 2000 W induction stove in full capacity, the daily electricity consumption will be 5.48 kWh. Normally for daily dishes like roti, fried vegetables, rice, lentils we can use the induction stove in about 40-60% of full capacity (Niraniya, 2023). In this case, the daily energy consumption considering three hours needed for cooking will be 4.1 kWh for using 1500W. If we take the highest rate of 15 A domestic category, the energy cost will be Rs. 11 per kWh. According to this, the total daily expenses will be Rs. 45.21 and monthly total of Rs. 1356.3 for 123.3 kWh. If the full capacity of the induction stove is utilized, the total expenses in a month will be Rs. 1808 for 164.4 kWh of electricity.

According to an analysis done on cooking energy on Nepali households by Saligram Pokharel, a family size of 6 people would consume 5.5 GJ of final energy for food (Pokharel, 2004). Taking the minimum efficiency of induction cooking 84%, a family size of 5.29 needs 481 MJ of energy monthly which turns out to be 134 kWh, costs Rs. 1474 per month (Pokhrel, 2022) (Jayasekara & Fernando, 2020).

Also considering the same amount of final energy analysis could be done on LPG gas energy, which is currently the most common commercial cooking fuel in practice. Taking the efficiency as 55% of LPG, 735 MJ of energy is required by a family size of 5.29. 735 MJ of LPG gas energy turns to be 16 KG of LPG gas (1 KG of LPG = 46 MJ in worst case) (Jayasekara & Fernando, 2020). The current cost of LPG gas refill per 14.2 KG cylinder is Rs. 1660 (NOC, 2023). The total monthly energy price for LPG is found to be Rs. 1870 without the addition of subsidy.

2.4.3 Comparison of Induction Stove with other electric stoves

Table 2.2 shows the cooking time and cooking energy consumption for cooking half cup of rice via Infrared Stove, Induction Stove and Mud Heater (Shrestha, Raut, & Shrestha, 2019). The cooking time required for an induction stove was found to be 7.82 minutes whereas the cooking time for infrared and mud heater were 19.33 minutes and 21.3 minutes. The induction stove is 60% faster in cooking as compared to infrared stove. The cooking time for the mud heater and infrared stove are almost similar. Also, the energy consumed by the induction cooker was 0.14 KWh whereas the infrared stove and the mud heater consumed more than double energy as compared to the induction stove. The induction stove can cook the food with 60% saving in energy as well as time as compared to infrared stove.

Another research done by (Chhetri, Lham, & Chhetri, 2021) shows the energy consumption using induction and infrared stoves for preparing different dishes which is summarized in Table 2.3.

Table 2. 2: Cooking time and energy consumption of different electric stoves (Shrestha, Raut, & Shrestha, 2019)

	Infrared Stove	Induction Stove	Mud Heater
Cooking time requirement (minute)	19.33	7.82	21.3
Energy Used (KWh)	0.35	0.14	0.32

Table 2. 3: Energy Consumption in cooking different dishes (Chhetri, Lham, & Chhetri, 2021)

	Energy Consumed, KWh	
Dish	**Infrared Stove**	**Induction Stove**
Rice 2-Cup	0.60	0.28
Water 2 liter	0.63	0.24
Milk 1 liter	0.27	0.14
Boiled Egg 3 Nos.	0.40	0.19

Table 2.3 shows that the infrared stove consumed about twice of the energy consumed by the induction stove. For water boiling using an infrared stove, the energy consumed is nearly 2.6 times higher than the induction stove. Table 2.2 and 2.3 shows that using Induction instead of infrared stove is beneficial in time saving, energy saving and obviously cost saving.

2.4.4 Types of Induction Stoves commonly used in households

The number of cooking zones or elements on an induction cooktop determines whether it is a one-burner, a two-burner induction stove or hybrid type.

i. **One-Burner Induction Stove (Single Element or Portable Induction Cooktop):**

  - **Design and Size:** These are compact units perfect for small spaces or for additional cooking needs. Given their size, they are easily portable.
  - **Utility:** Suitable for those who live alone, students in dorm rooms, or people in temporary housing. It's also handy for those who entertain often and require an extra burner for big meals.

- **Features:** Many single-burner units come with multiple power settings, temperature control, and safety features like automatic shut-off.
- **Portability:** Given its size, this type is easily portable, making it ideal for traveling, camping, or temporary setups.
- **Power Consumption:** The single burner induction cooker ranges from 1200 W to 2200 W (Daraz, 2023).

ii. **Two-Burner Induction Stove:**

- **Design and Size:** These are larger than the single-burner units but are still relatively compact compared to full-size cooktops. They provide two separate cooking zones, which can operate independently.
- **Utility:** Suitable for small families, couples, or individuals who often cook multiple dishes simultaneously. It's also useful in small apartments or homes without a full kitchen.
- **Features:** Typically, these come with individual controls for each burner, allowing you to cook at different temperatures simultaneously. They may also include advanced features like touch controls, timers, and safety sensors.
- **Portability:** While these are less portable than single-burner units due to their size, some models are still designed for easy movement or temporary setups.
- **Power Consumption:** The power consumption of two burner induction stoves generally found to 2000 W+2000 W (2000 W in each burner) (Daraz, 2023).

iii. Hybrid type Induction Stove

A hybrid induction cooker or cooktop refers to a cooking surface that combines traditional electric or gas heating elements with induction heating elements. By offering both types of cooking methods on a single surface, it allows users the flexibility to use any type of cookware, whether or not it's compatible with induction cooking.

Here are some features and advantages of hybrid induction cookers:

- **Versatility**: Not all pots and pans are induction-compatible. With a hybrid cooktop, you're not limited by the type of cookware you can use.
- **Efficiency**: Induction cooking zones heat up faster and provide precise temperature control, making them more energy-efficient compared to traditional electric or gas burners.
- **Safety**: Induction cooktops only heat the cookware and not the surrounding surface, making it safer and cooler to the touch than traditional cookers.
- **Easy Cleaning**: Since the induction zones don't get hot like traditional burners, there's less chance of spills getting baked onto the surface, making cleaning easier.
- **Space-saving**: In smaller kitchens, a hybrid cooktop can offer the best of both worlds without requiring the space for two separate appliances.
- **Cost**: While hybrid cooktops can be more expensive than traditional cooktops, they may be more cost-effective than purchasing both an induction cooktop and a traditional electric or gas cooktop separately.
- **Power Consumption**: Generally, the hybrid type induction stove can be found to have one induction stove and another infrared stove. The power requirement in most stoves is 2000 W + 2000 W (Daraz, 2023).

When purchasing a hybrid induction cooker, it's essential to check the number of induction zones versus traditional zones, as configurations can vary. Some might offer an equal number of each, while others may lean more heavily towards one type of heating method. Also, be aware that the power requirements for such cooktops can be different from standard cooktops, so always check the product specifications.

2.5 Relevant National Policies

Nepal has been developing various plans internally through National Five-Year Plans, Budget Speech, Ministries, and various organizations within and have defined a set of targets to achieve those plans. Similarly, plans and targets are also set in coordination with international organizations such as UNFCCC and UNDP. Many plans and targets are directly related to energy and electricity consumption. The Government of Nepal formulates various policies to achieve these targets through related line ministries and organizations within the ministries. Ministry of Energy, Water Resources and Irrigation

(MOEWRI) had issued an Energy white paper in 2018 with plans for Electric cooktop in every home, 50% of imported vehicles to be electric, upgraded/developed substations for reliable supply to an industrial corridor with a capacity of at least 5000 MW and others plans to be implemented within next five years. Similarly, the 15th National Five-Year plan has prioritized the electricity distribution master plan. In addition, the Government of Nepal, through budget speech for 2078/079, has reduced the customs duty on electric cooking appliances and reduced excise duty on electric vehicles to encourage consumers to increase the electrical load in their household and surrounding.

Nepal also has submitted its Second Nationally Determined Contribution, 2020 to UNFCCC, where it is ensured that 25% of households use the electric stoves as their primary means of cooking and increase the sale of electric vehicles to cover 90% of all private passenger vehicle sales, including two-wheelers and 60% of all four-wheeler public passenger vehicle sale by 2030 (GoN, 2020). Similarly, Nepal has set an SDG target through UNDP for accessibility of 99% of households to electricity, improved universal use of high-efficiency appliances, and per capita, electricity consumption increased to 1500 kWh all by 2030. According to the report published by the Ministry of Forests and Environment in the year 2020 around 6% of the household use electric stoves as their primary medium of cooking (Division, 2021).

2.6 Forecasting

The term "forecast" refers to anticipated load requirements that are calculated using a defined method of defining future loads with inadequate quantitative clarity to allow for the making of crucial system expansion decisions. Load forecasting is typically done for optimal supply planning, fuel mix selection, efficient power procurement, capital investment for generation and transmission, financial forecasts, and capacity and network planning for distribution and transmission systems. The ability to forecast long-term electricity demand is a fundamental prerequisite for developing a secure and economic power system (Hahn et al., 2009). Also, the demand forecast is used as a basis for system development and for determining tariffs for the future. Decision making is a complex process in the electricity sector, as various levels have to be considered which comprise the planning of day-to-day operation of generation units and their optimal use as well as the flow of power. These decisions address and affect widely different aspects of the system and time-horizon. For such planning and decision-making, load forecasts are very important. Forecasts made for day-to-day operation of the power system (Kyriakides & Polycarpou, 2007) requires the prediction of the load for a day ahead, whereas the decision whether to invest in a major structure requires a far longer horizon of prediction. Load forecasts can be classified in the horizon of time as: short-term load forecasts which usually aim to predict the load up to one week ahead; medium-term load forecasts which predict the load from up to one year, and long-term load forecasts are usually up to 20 years although longer lead times of 25–30 years can be found. The decision-maker is faced with the task of selecting an appropriate model type as well as determining important external factors such as weather conditions over seasonal effects to socio-economic factors which usually depend on each other. Various methods are applied to load forecasting (Feinberg & Genethliou, 2005; Kyriakides & Polycarpou, 2007; Taylor & McSharry, 2007).

Regression is one of the most commonly used statistical techniques used in load forecasting. For electric load forecasting, regression methods are usually used to model the relationship between load consumption and factors such as weather, day type, and customer class. Time-series methods assume that the data have an internal structure, such as autocorrelation, trend, or seasonal variation and have been used for decades in such fields as economics, digital signal processing, and electric load forecasting. Artificial neural networks (ANN or simply NN) have been a widely studied electric load forecasting technique since 1990. Neural networks are essentially nonlinear circuits with the demonstrated capability to do nonlinear curve fitting (Taylor & McSharry, 2007). The outputs of an ANN are some linear or nonlinear mathematical function of its inputs which may be the outputs of other network elements and actual network inputs. Among the mentioned models, Regression models are quite common in load forecasting (Kyriakides & Polycarpou, 2007). They have used rate to model the relationship between the load and external factors, for instance, weather and calendar information or customer types (Feinberg & Genethliou, 2005). Regression methods are relatively easy to implement where the relationship between input and output variables is easy to realize. Regression models also allow comparatively simple performance evaluations (Hahn, Meyer-Nieberg, & Pickl, 2009).

2.6.1 Least Square Regression Model

The regression technique is a standard statistical approach to approximate future demand. Regression techniques are used to model the electric load as a function of load consumption in relationship with different dynamics like seasonal patterns, meteorological changes, day type, consumer social class, etc. In the regression technique, the correlation between a dependent variable, and one or more independent variables are modeled for analysis. The dependent variable is the response variable, while independent variables are called descriptive or predictor variables (Halepoto et al., 2014). The Least Squares Regression method is the optimal approach when the model's form is known already, and the only interest is to find its parameters. The least squares approach minimizes the difference of the independent estimators of the coefficients so that the estimated error is minimized to zero (Halepoto et al., 2014). In comparison with the linear and nonlinear approach, the non-linear regression method generates more precise results because it can fit the broad range of data sets and functions.

2.7 Curve fitting and Forecasting Models

2.7.1 Curve Fitting

Curve fitting is a process in statistics and machine learning where you try to find the best possible curve that fits the provided data points. The goal is to create a curve that is as close as possible to all the data points, and this is usually done using different types of regression techniques. These curves can be used to understand the data better, make predictions, or identify trends and patterns.

The most commonly used curve fitting techniques include:

i. Linear Regression: It models the relationship between two variables by fitting a linear equation to observed data.

ii. Polynomial Regression: It models the relationship between the independent and dependent variables as an nth degree polynomial. Polynomial regression can model relationships where the rate of change in the dependent variable varies with respect to the predictor.

iii. Exponential and Logarithmic Regression: These types of regression are used when data has exponential relationships or when the rate of change in the data increases or decreases exponentially.

iv. Nonlinear Regression: This technique is used when the dependent or target variable is a nonlinear function of the model parameters. This type of regression is much more flexible than the techniques listed above but is also more complex to use and understand.

v. Spline Regression: This technique uses piecewise polynomials to perform the curve fitting. Splines are useful in situations where the relationship between variables is highly nonlinear and the domain can be broken up into pieces, each of which can be approximated with a polynomial.

The optimal curve fit is typically determined using a least squares approach, which minimizes the sum of the squared residuals (i.e., the differences between the observed and predicted values).

2.7.2 Linear Forecasting Model

A linear forecasting model is a statistical tool used in forecasting trends, typically within time series data. These models predict future data as a linear function of past data.

There are several types of linear forecasting models, some of the most common include:

i. Simple Linear Regression: This is the simplest form of linear forecasting where the model makes predictions based on a single independent variable. In the case of time series data, time is often used as the independent variable to forecast future values.

ii. Multiple Linear Regression: This extends the simple linear regression model by including multiple independent variables. This model assumes that the relationship between the dependent variable and multiple independent variables is linear.

iii. Autoregressive (AR) Model: In this model, future values are predicted based on past values of the same series. An AR model is typically represented as AR(p), where 'p' is the number of past values used to forecast future values.

iv. Moving Average (MA) Model: This model is based on the premise that the future value of a variable is a function of the average of the past errors or residuals.

v. Autoregressive Integrated Moving Average (ARIMA): This is a generalized version of an AR model but includes differencing to make the time series stationary (i.e., remove trends or seasonality) and a moving average component.

Linear forecasting models are straightforward, easy to understand, interpret, and compute, making them highly useful in various areas, including economics, business, and finance. However, they are based on the assumption that the underlying system follows a linear process, which might not always be the case. If the system is nonlinear or if there are abrupt changes in trends or seasonal variations, linear models may not be the best choice. Advanced techniques like machine learning and deep learning models may provide better accuracy in such cases.

2.7.3 Polynomial Forecasting Model

A polynomial forecasting model is a type of regression model that fits a nonlinear relationship between the independent variable (X) and the dependent variable (y).

The advantage of polynomial regression is that it can model relationships that are not merely linear but have some sort of curve. This allows it to fit a wider range of data than a simple linear model.

However, choosing the right degree of polynomial is important. Too low a degree, and the model may not capture the complexity in the data (underfitting); too high a degree, and the model may become overly complex and capture noise in the data (overfitting).

Polynomial models are commonly used in time series forecasting when there are complex trends that a linear model cannot capture. For instance, they can capture seasonal trends, such as peaks and valleys in electricity demand or retail sales.

It's important to note that while polynomial models can fit complex trends, they are not always the best choice for forecasting, especially when dealing with long-term predictions. This is because high degree polynomial models can exhibit extreme behavior at the boundaries of your data. Hence, they might predict unrealistically high or low values in the future. Therefore, care should be taken when extrapolating using polynomial models.

2.7.4 Goodness of Fit

"Goodness of fit" refers to how well a statistical model fits a set of observations. Measures of goodness of fit typically summarize the discrepancy between observed values and the values expected under the model in question. Such measures can be used in fitting and comparing models of different complexities. Here are few common goodness of fit measures:

i. R-squared (Coefficient of determination): This statistic indicates the proportion of the variance in the dependent variable that is predictable from the independent variables. It ranges from 0 to 1, with 1 indicating a perfect fit. An R-squared of 0 indicates that the model explains none of the variability of the response data around its mean.

ii. Adjusted R-squared: This is a modified version of R-squared that adjusts for the number of predictors in the model. It is particularly useful when comparing models of different complexities (i.e., with different numbers of predictors), as it penalizes the addition of uninformative predictors.

iii. Akaike Information Criterion (AIC): This is a measure used to compare different models and select the best one. It takes into account the complexity of the model and the goodness of fit. Lower AIC values indicate better-fitting models.

iv. Bayesian Information Criterion (BIC): This is similar to AIC, but it applies a stricter penalty for models with more parameters, thus favoring simpler models than AIC does. As with AIC, lower BIC values indicate better-fitting models.

v. Mean Squared Error (MSE) or Root Mean Squared Error (RMSE): These are measures of the average squared difference between the observed and predicted values. Lower values indicate better-fitting models.

vi. Residual Standard Error (RSE): This is an estimate of the standard deviation of the residuals. Lower RSE indicates a better fit.

vii. Log-Likelihood: It measures the likelihood that the model would produce the observed data. Higher log-likelihood values indicate better-fitting models.

CHAPTER THREE: RESEARCH METHODOLOGY

To fulfill the objective of the mentioned title, this study is targeted accordingly. Madhesh Province of Nepal is selected for the study. The works are carried out according to the flow chart illustrated in Figure 3. 1.

3.1 Flow Chart

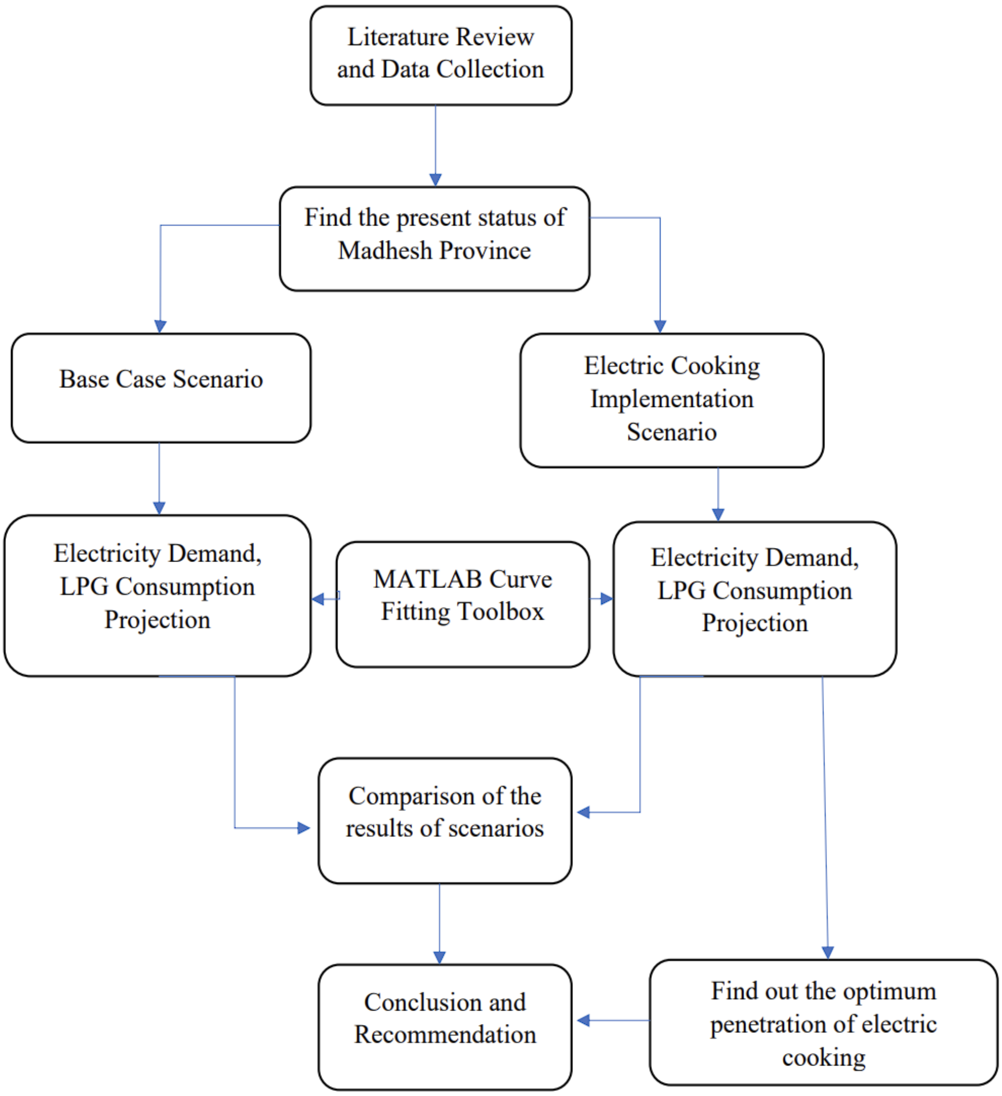

Figure 3. 1: Flow Chart

3.2 Data Collection

The data were collected from the published journal papers, reports and other electronic sources. The consumer, consumer category, energy consumption, loss unit data and Substation loading data were collected from NEA Grid Department.

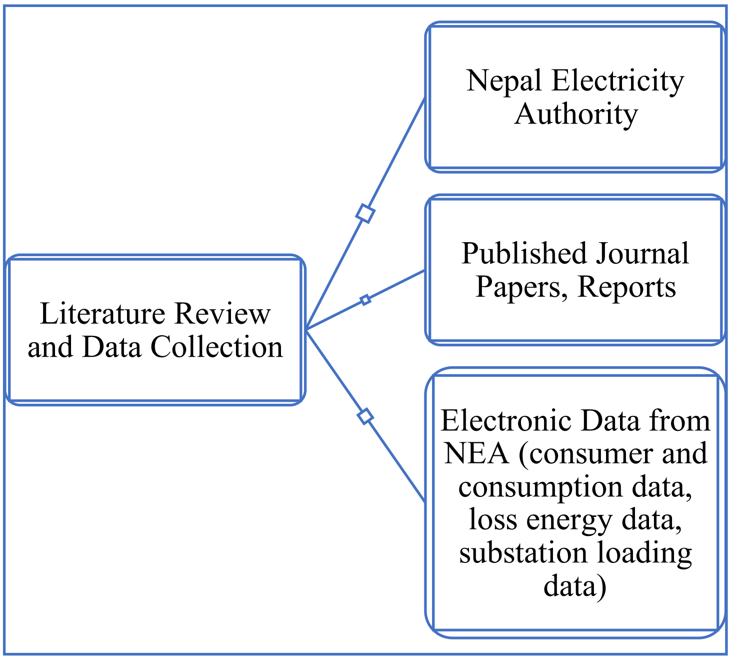

Figure 3. 2: Literature Review and Data Collection

3.3 Polynomial Forecasting Model

The general form of a polynomial equation is:

$$y = b_0 + b_1x + b_2x^2 + b_3x^3 + \ldots + b_nx^n \quad (3.1)$$

Where:

y is the dependent variable (the variable we want to predict or forecast)

x is the independent variable (the variable we are using to make the prediction)

$b_0, b_1, b_2, \ldots, b_n$ are the regression coefficients. These indicate the influence that each corresponding term (i.e., $x, x^2, x^3, \ldots, x^n$) has on y.

When n=1, the polynomial equation in equation 3.1 becomes a linear equation.

Goodness of fit: R-squared

R-squared, also known as the coefficient of determination, is a statistical measure that represents the proportion of the variance for a dependent variable that's explained by an independent variable or variables in a regression model.

The formula for R-squared is:

$$R^2 = 1 - (SSR/SST) \quad (3.2)$$

where:

- SSR is the sum of squares of the regression (also called the residual sum of squares), which is the sum of the squares of the difference between the predicted values and the mean of the dependent variable.
- SST is the total sum of squares, which is the sum of the squares of the difference between the observed values and the mean of the dependent variable.

Essentially, R-squared compares the fit of the chosen model with that of a horizontal straight line (the mean of the observed responses). If the chosen model fits worse than a horizontal line, then R-squared is less than 0. If the model fits perfectly, R-squared is equal to 1.

The forecasting procedure is illustrated in Figure 3.3.

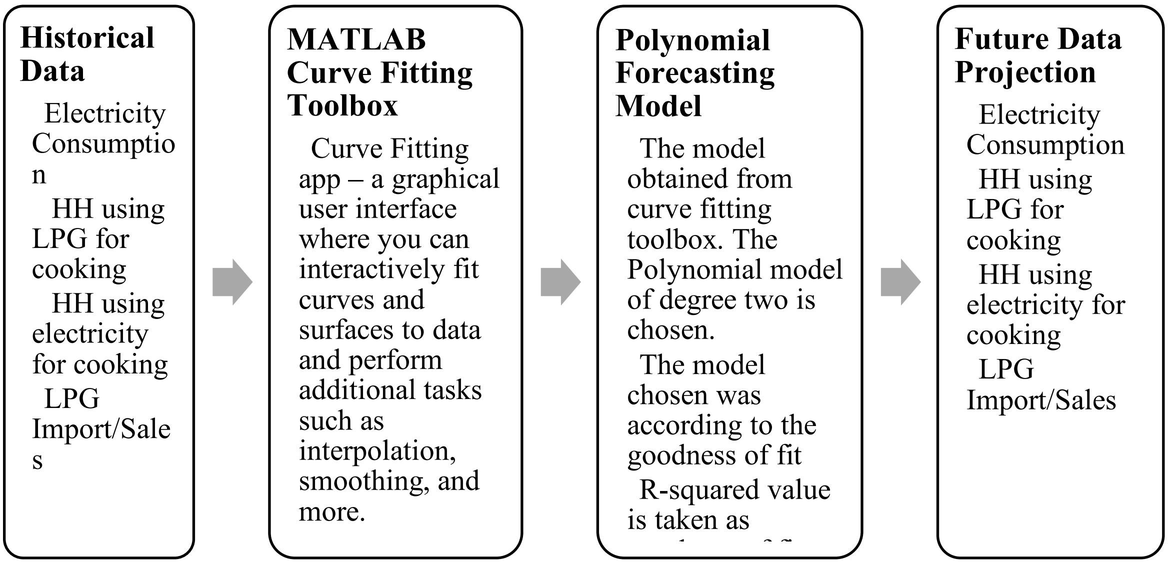

Figure 3. 3: Forecasting Process

3.4 Scenario Development

Two scenarios are developed to fulfill the objectives of the study as shown in Figure 3.4.

i. Base Case Scenario

ii. Electric Cooking Implementation Scenario

In the base case scenario, the usual growth of households using different cooking fuels are calculated for the future. Also, electricity consumption is forecasted as per the historical electricity consumption pattern in Madhesh Province using MATLAB Curve Fitting Toolbox.

In the electric cooking implementation scenario, the distribution of households using electricity is projected according to the target of implementing electric cooking in 25% of total households up to 2030. Also, the total electricity consumption is addition of base case consumption and electricity consumption by additional electric cooking load in every year is calculated in electric cooking implementation scenario. The optimal penetration of electric cooking is analyzed based on the feeder loading and substation loading condition.

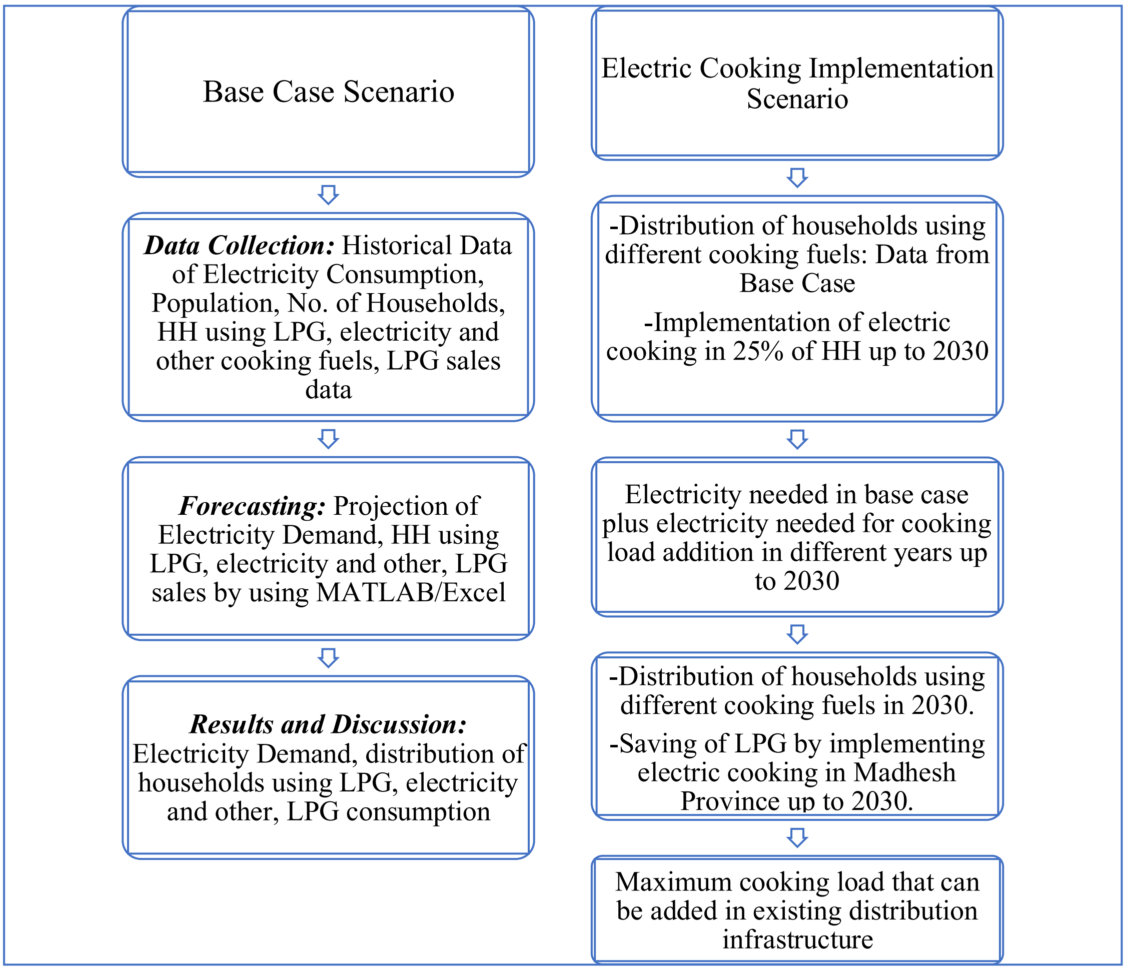

Figure 3. 4: Scenario Development

3.5 Software and Tools used

The analysis was done with MATLAB (MATLAB R2018) and Microsoft Excel. The report writing is accomplished with Microsoft Word.

3.3.1 MATLAB

MATLAB (short for Matrix Laboratory) is a high-performance language developed by MathWorks for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

MATLAB is used by engineers and scientists in many fields such as image and signal processing, communications, control systems for industry, smart grid design, robotics as well as computational finance.

Curve Fitting in MATLAB

polyfit function: This is a basic function for fitting a polynomial to data. *polyfit* returns the coefficients for a polynomial of a specified degree that is a best fit (in a least-squares sense) for the data.

Curve Fitting Toolbox: This is a more powerful and flexible toolbox for curve fitting. It includes the *cftool* command, which opens a Curve Fitting app – a graphical user interface where you can interactively fit curves and surfaces to data and perform additional tasks such as interpolation, smoothing, and more.

fit function: This function from the Curve Fitting Toolbox allows you to fit data using a wider range of models, including custom equations.

In all cases, it's important to visualize your fitted curve with the original data to ensure that the fit is good. You can do this using the *plot* function in MATLAB.

CHAPTER FOUR: RESULTS AND DISCUSSION

The main goal of this study is to analyze the electricity demand and LPG saving opportunity by implementing electric cooking in Madhesh Province. As per the main and objectives, the results are obtained by using the research methodology. The results obtained from this study are discussed in the following subsections.

4.1 Population and Household Growth

The average growth rate of population is taken as 1.29% and average growth rate of households is taken as 2.18% in future for Madhesh Province from the Census data.

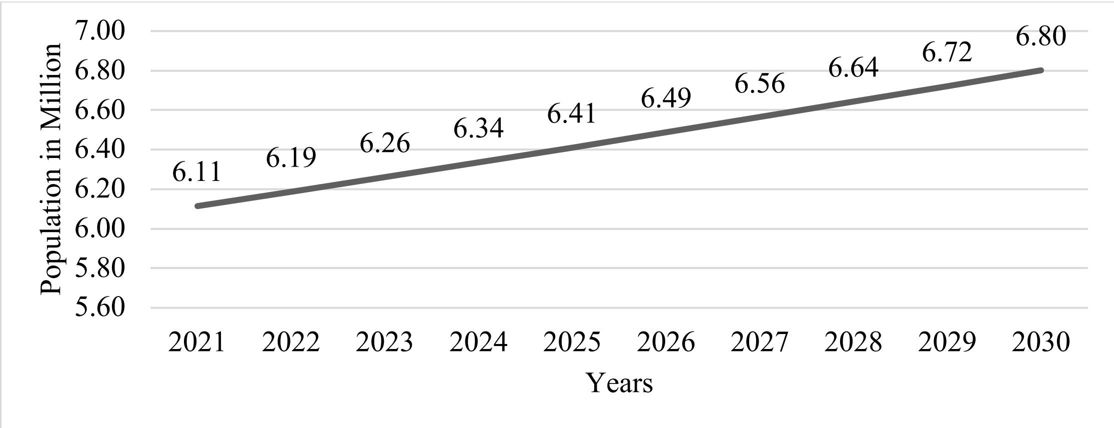

Figure 4. 1: Population Projection

The population of Madhesh Province in 2021 is 6.11 million will rise to 6.80 million in 2030 with an annual average population growth rate of 1.29% as shown in Figure 4.1.

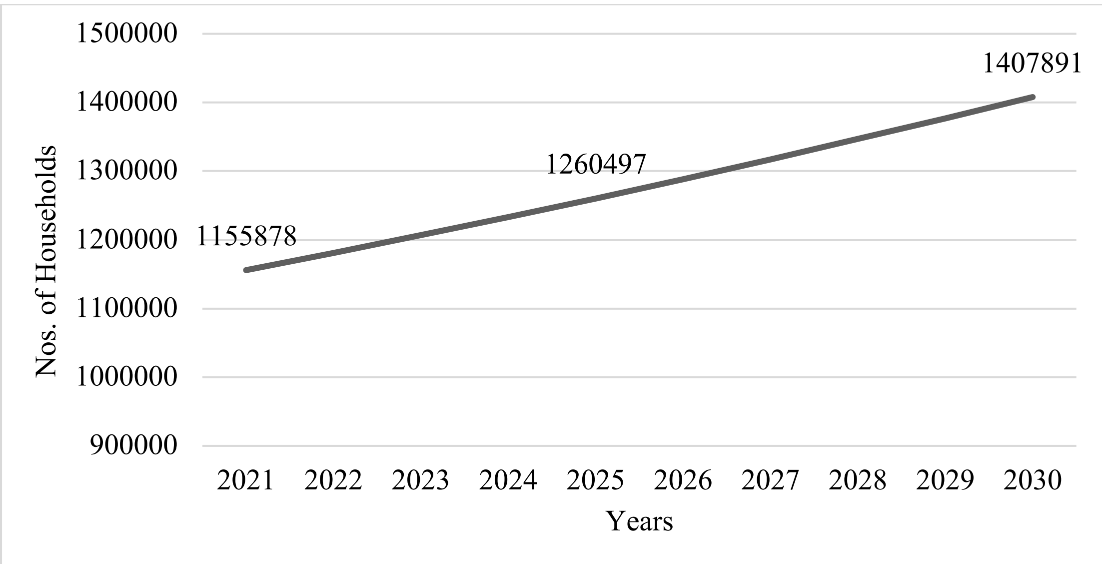

Figure 4. 2: Household Projection

With the rise in population, the number of households will also increase. The number of households will rise by 24.1 % from 2011 to 2021. Also, the household size is decreasing as per the past data, which was 5.80 in 2011 and became 5.29 in 2021. The household size will be 4.89 person per house in 2030. The number of household projections up to the year 2030 is shown in Figure 4.2.

4.2 Base Case Scenario

4.2.1 Share of Households using different cooking fuels

By using the past data, the number of households using LPG can be fitted to the curve using MATLAB Curve fitting toolbox. The equation 3.1 is used to fit the curve.

The polynomial model of degree two for domestic electricity consumption obtained from the MATLAB Curve Fitting Toolbox in base case scenario is given below:

$$f(x) = p_1x^2 + p_2x + p_3 \qquad (4.1)$$

The Coefficients (with 95% confidence bounds) were obtained as:

p1 = 2184

p2 = 541.8

p3 = 56634.41

The R-square value for this model is obtained as 0.99.

Also, for the number of households using electricity as a main fuel for cooking, the same polynomial regression model is used and the Coefficients (with 95% confidence bounds) were obtained as:

p1 = 126.21

p2 = -719.2

p3 = 1297.7

The R-square value for this model is obtained as 0.99.

As per the fitting model mentioned in equation 4.1, the future data can be obtained and the curve in Figure 4.3 is developed. The households using other cooking fuels are the remaining number of households.

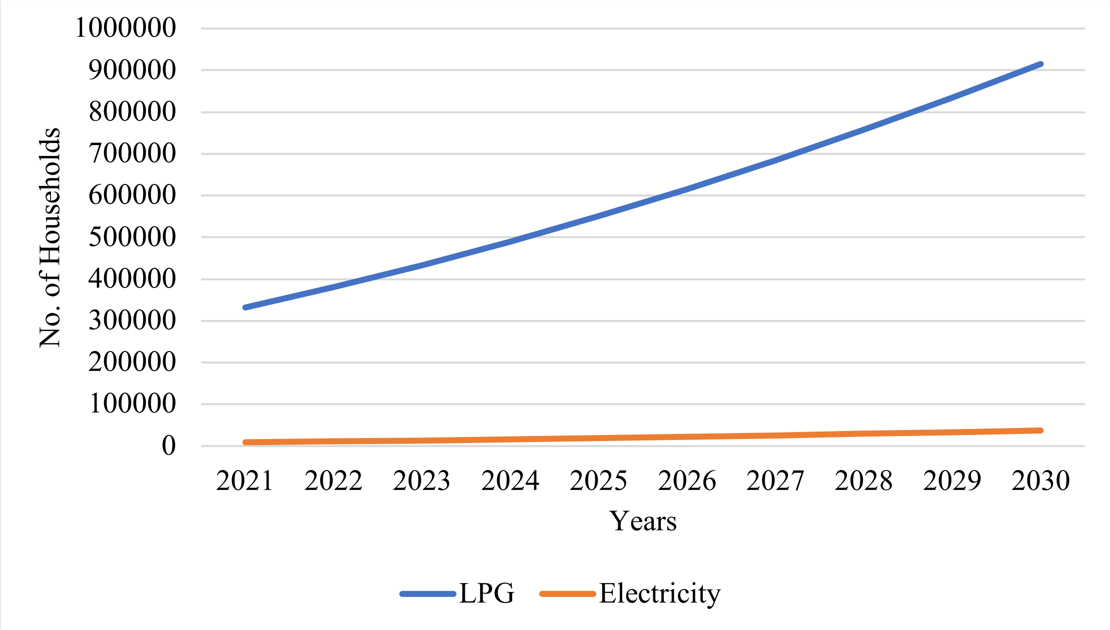

Figure 4. 3: No. of Households using LPG and Electricity

From Figure 4.4 we can see that the share of households using traditional cooking fuel is decreasing and households using LPG for cooking will be higher than the traditional cooking fuel after 2027 if we consider the current rising trend of LPG usage.

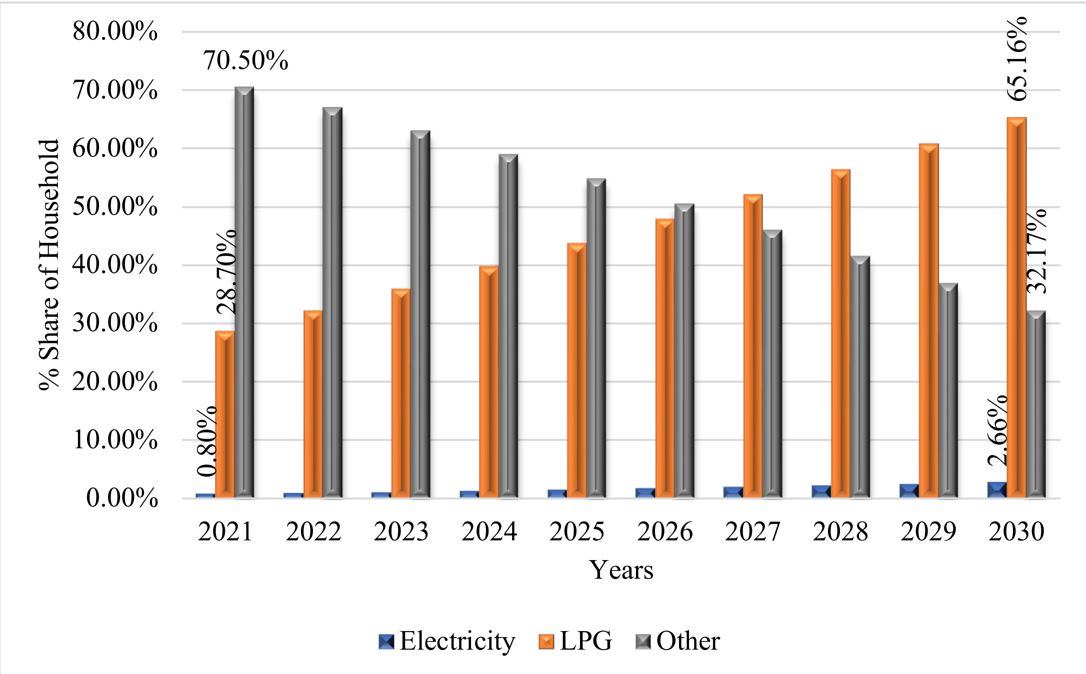

Figure 4. 4: Distribution of household using different fuels for cooking in base case scenario

As seen from Figure 4.4, the share of households using other cooking fuels than LPG and electricity is reducing from the year 2021 to 2030 which can also be seen from

Figure 2.10. The shifting of cooking fuels from traditional to commercial can be seen from past history which is also reflected in future years. The share of households using LPG is seen rapidly growing in the future and will be 65% in 2030. The share of households using traditional cooking fuels will be reduced to 32.17% in 2030 which is 70.50% in 2021. The share of households using electricity as a main fuel for cooking is increased to just 2.66% up to 2030.

4.2.2 Electrical Energy Demand

The domestic demand in 2021 is 587 GWh and total demand is 2229 GWh including loss units. By taking the past trend as shown in Figure 2. 18, the future demand of electricity is forecasted. The distribution loss in 2021 was 14.17% which is assumed to be reduced to 12% in 2030.

The consumption pattern is plotted in MATLAB curve fitting toolbox for both the domestic demand and non-domestic demand of electricity to find the future electricity in base case scenario.

The polynomial model of degree two as given in equation 4.1 is used for domestic electricity consumption curve fitting.

The Coefficients (with 95% confidence bounds):

$p_1 =$ 3887.289

$p_2 =$ 3297.1

$p_3 =$ 168398.597

The R-square value for this model is obtained as 0.99.

For other consumption (non-domestic consumption), the Coefficients (with 95% confidence bounds) were obtained as:

$p_1 =$ 11179.025

$p_2 =$ -33152.411

$p_3 =$ 472834.327

The R-square value for this model is obtained as 0.92.

From the polynomial model as mentioned in Equation 4.1 with the coefficients, the future value of domestic and other sector's electricity consumption is calculated. The required electricity up to 2030 is shown in Figure 4. 5.

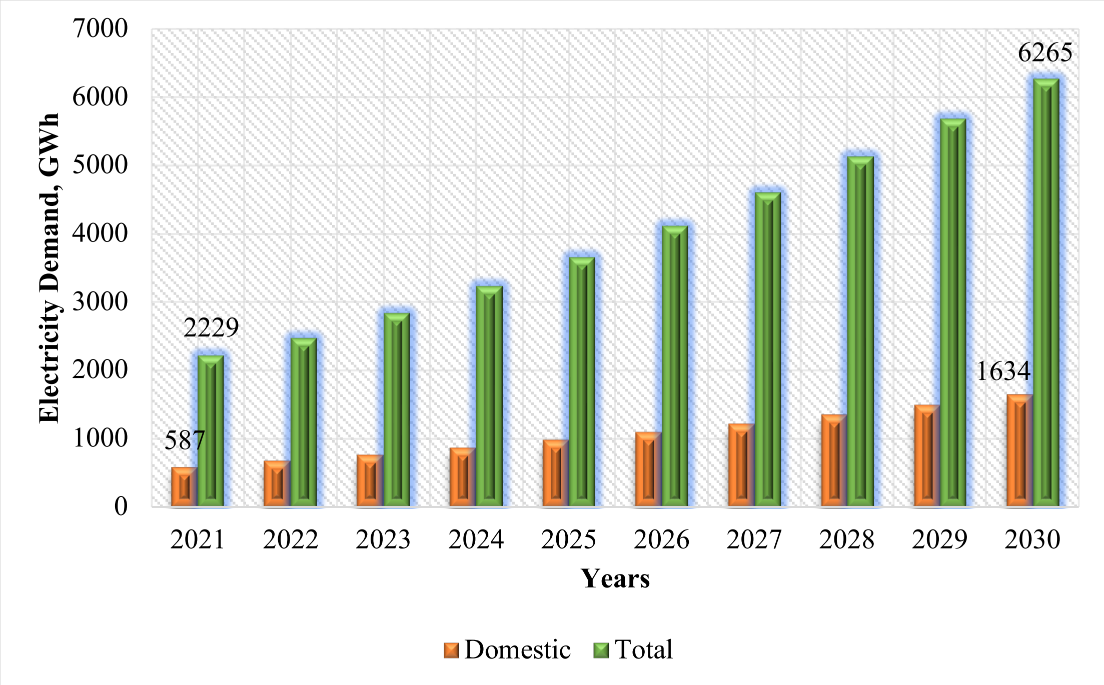

Figure 4. 5: Electricity demand in base case scenario

Figure 4. 5 shows that the domestic electricity demand will be 1634 GWh and total electricity demand will be 6265 GWh in 2030 which is an increase of 4036 GWh from the year 2021. The electricity demand forecasted by Distribution System/Rural Electrification Master Plan (NEA) for year 2030 is 5912 GWh in case of Madhesh Province. The forecasted value in this study is near the demand value forecasted by Distribution System/Rural Electrification Master Plan (NEA) for Madhesh Province.

4.2.3 Peak Demand

As per the electricity used by different sectors, the peak demand needed is calculated according to the annual load factor. The annual load factor for 2021 is 65%. The load factor considered by the Distribution System/Rural Electrification Master Plan (NEA) was 54% on average from 2023 to 2035. In this study, a load factor of 60% is taken for future peak demand projection. The peak demand requirement in the base case scenario is illustrated in Figure 4.6.

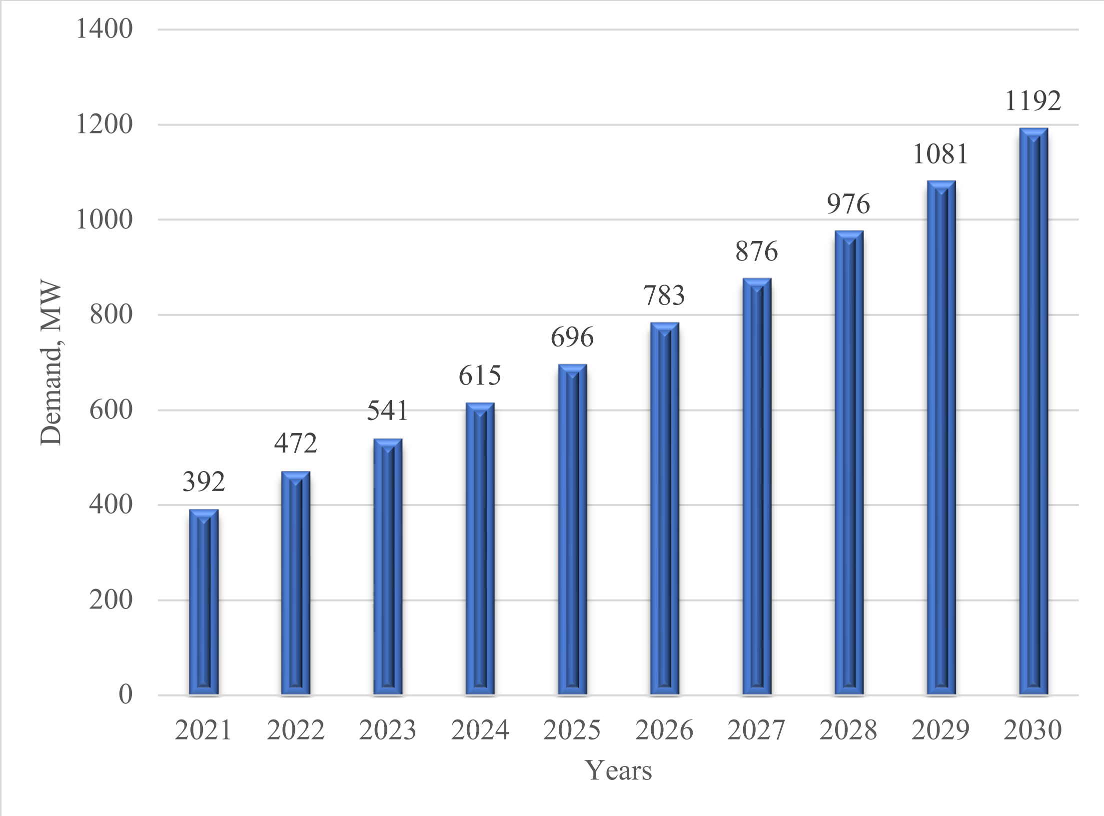

Figure 4. 6: Peak Demand in Base Case Scenario

In 2030, the peak demand will rise three times higher than the demand in 2021. The peak demand will be 1192 MW in 2030 which is near about the demand forecasted by Distribution System/Rural Electrification Master Plan (NEA) for Madhesh Province (1488 MVA) considering the power factor of 0.8.

4.3 Electric Cooking Implementation Scenario

4.3.2 Share of Households using different cooking fuels

As per the target of implementing electric cooking in 25% households for cooking purposes by 2030, the number of households using different cooking fuels are shown in Figure 4.7. The share of Households using traditional cooking fuels in both scenarios is considered the same. Households shifting their cooking fuels towards the commercial fuels will be assumed to be shifted to electricity from LPG in the electric cooking implementation scenario.

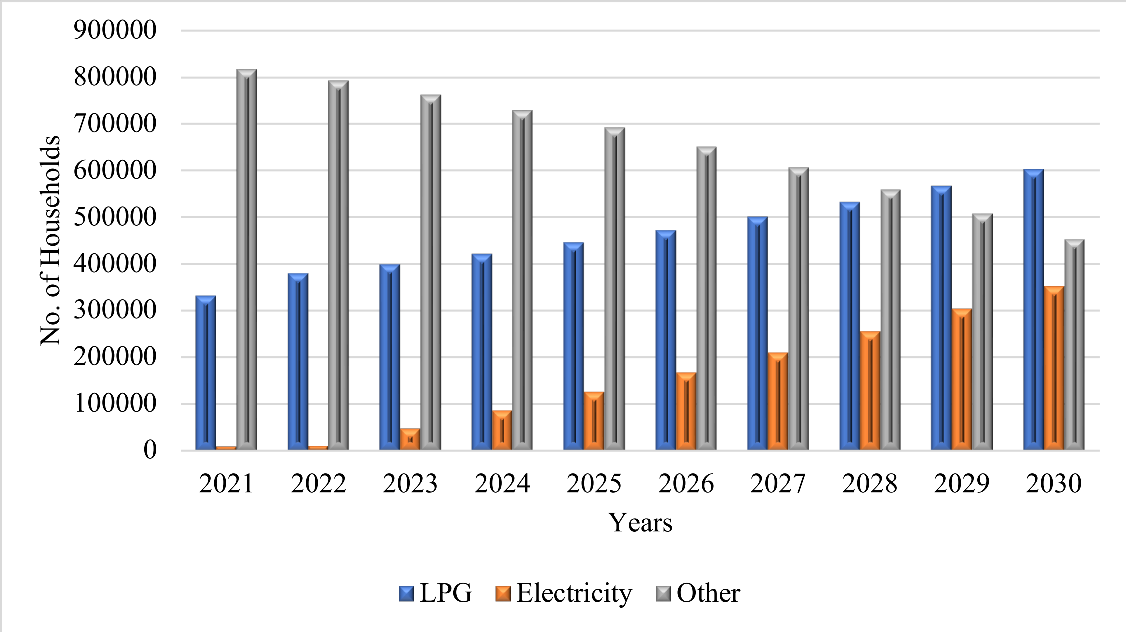

Figure 4. 7: Households using different cooking fuels in electric cooking implementation scenario

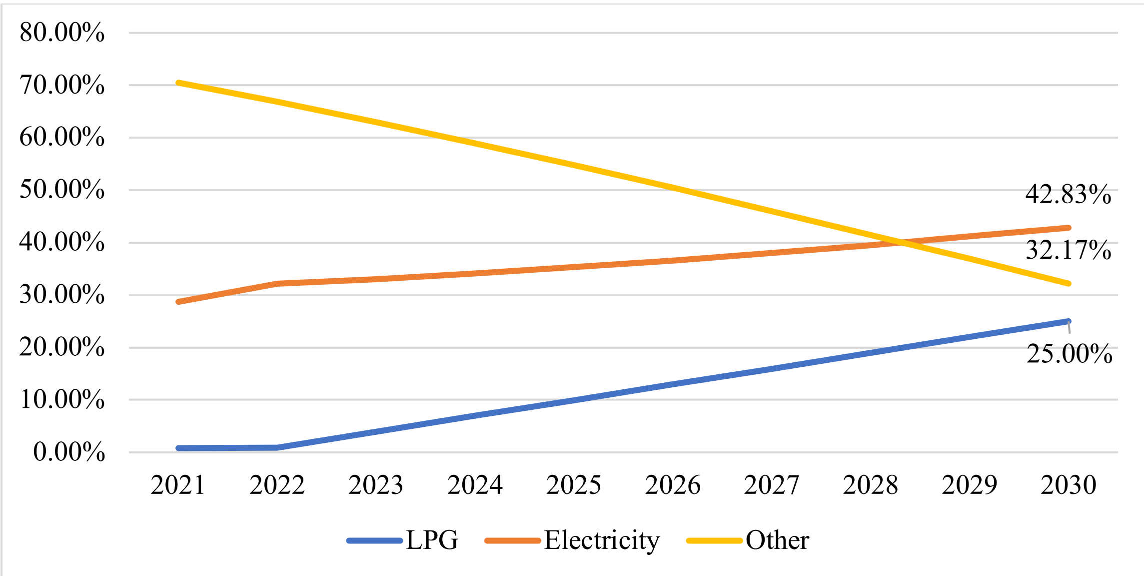

Figure 4. 8: Distribution of Household in electric cooking implementation scenario

Figure 4.8 illustrates that after electric cooking implementation, the share of households using LPG is reduced to 42.83% which is 65.16% in the base case scenario. This is because we assume that households shifting to commercial cooking fuel will shift to electric cooking. The share of households using traditional cooking fuel is the same as in the base case scenario as we consider the shifting from traditional to commercial and to electricity.

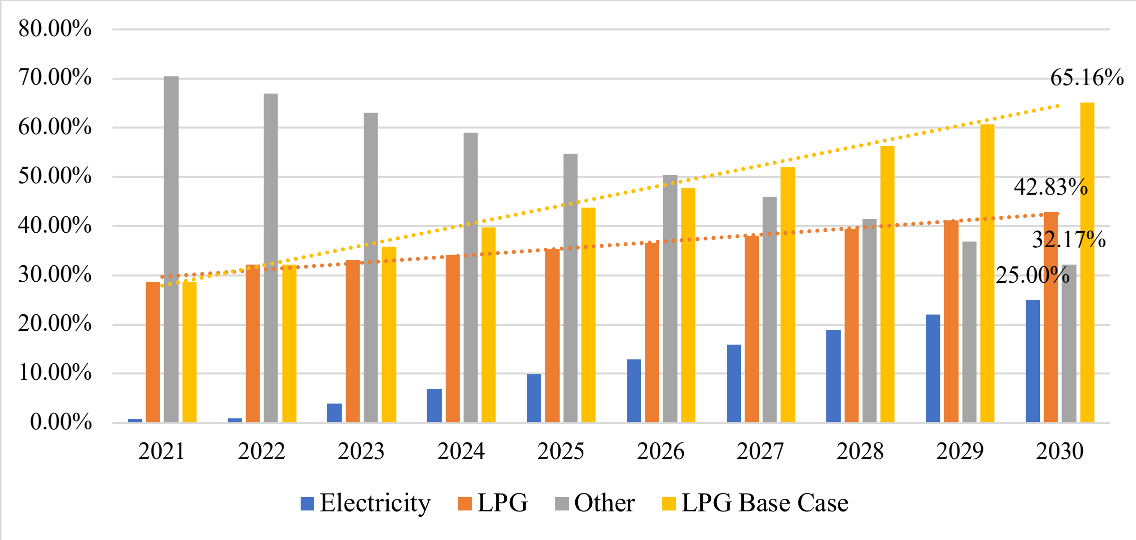

Figure 4. 9: Distribution of Households using different cooking fuels

Figure 4. 9 shows the share of households in both scenarios. Which shows that the use of traditional cooking fuel is sharply decreasing as commercial fuel use is increasing rapidly.

4.3.3 Electrical Energy Demand

By implementing electric cooking in Madhesh Province, electricity demand will rise as compared to the current electricity demand scenario. The electricity consumption is divided in two sectors: domestic and non-domestic sectors. The consumption in the domestic sector will be the total of normal use as per the past trend plus electricity needed for electric cooking in future years.

After the implementation of electric cooking in Madhesh Province, the domestic demand for electricity will increase. The demand for other sectors is assumed to be the same as demand in the base case scenario. An induction stove having two pot capacities of 4000 W (2000 W+2000 W) is used for the analysis in this study. The cooking power requirement is assumed to be 2500W (1500W+1000W) as many dishes can be made in this power and load beyond 2500W may not be exceeded as per the approved meter capacity of the consumer (15 Ampere). The daily average energy requirement is 4.45 KWh for a family size of 5.29 people.

After adding the cooking load to the system, the additional electrical energy requirement of total households as per the penetration level is calculated. Figure 4. 10 shows the required electricity in different years after implementing electric cooking.

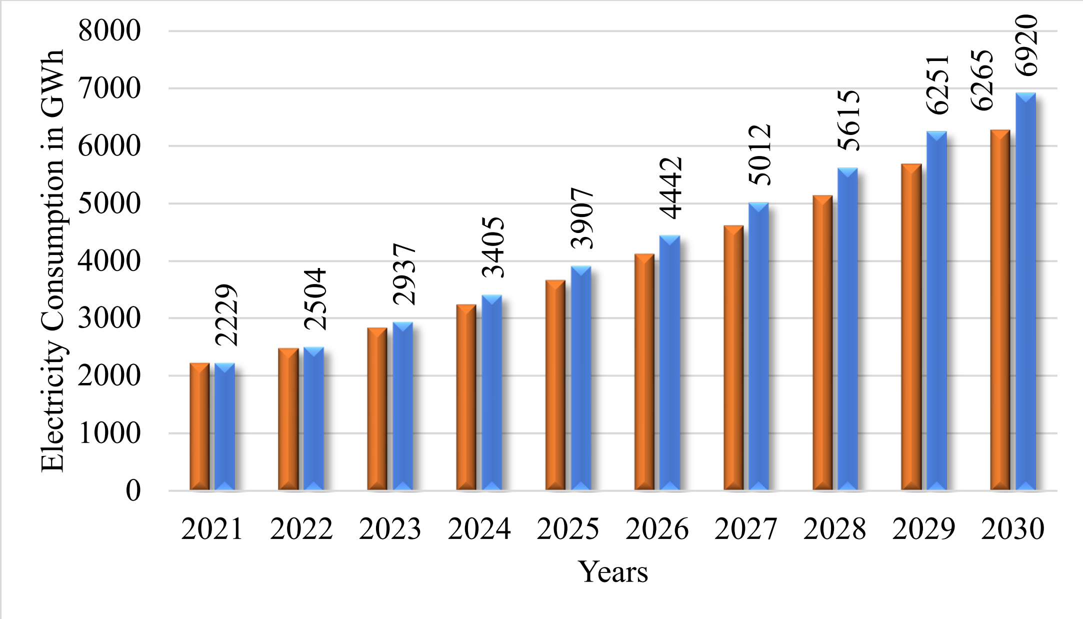

Figure 4. 10: Electricity requirement in Base Case scenario and electric cooking Implementation scenario

The electricity consumption in 2030 will be 6920 GWh which is 10.45% higher than the base case demand (6265 GWh). In 2030, a total of approximately 351,085 households will use electric cooking. The per capita consumption of Madhesh Province in base case scenario and in electric cooking implementation scenario is illustrated in Figure 4. 11.

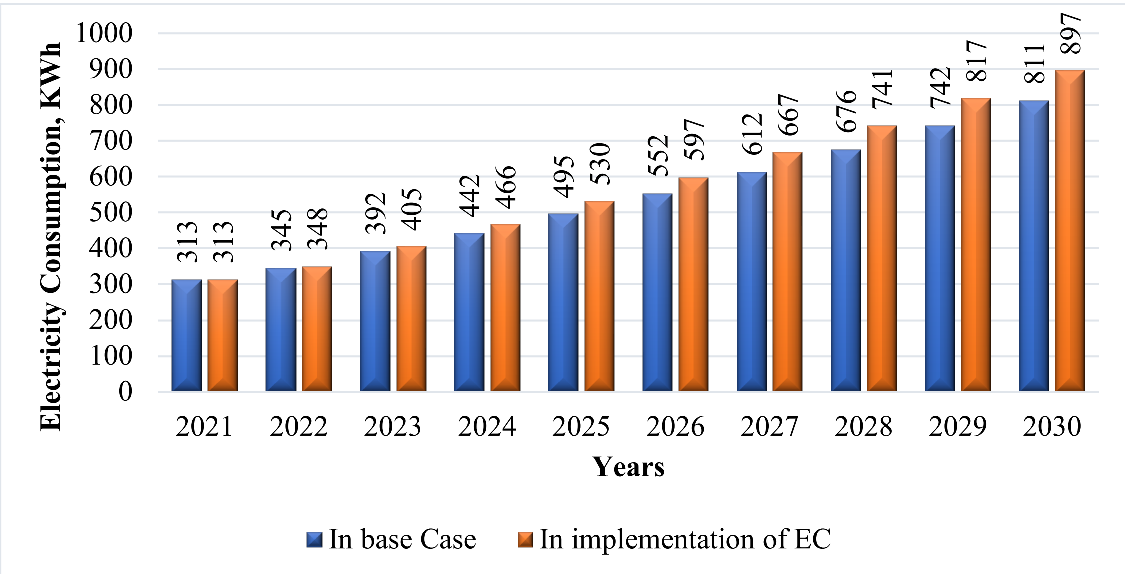

Figure 4. 11: Consumption per Capita in Base Case scenario and electric cooking implementation scenario

The per capita consumption of electricity in the base case scenario increased from 313 KWh in 2021 to 811 kWh in 2030. After electric cooking implementation, per capita consumption will increase to 897 KWh in 2030, which is 10.6% higher than the consumption in the base case scenario.

4.3.2 Peak Demand

The energy demand for different years should be fulfilled by the domestic generation or import of electricity from other countries. To fulfill the demand, adequate availability of distribution substations and grid substations will be necessary. Since distribution system upgradation and reinforcement are going on in Madhesh Province by NEA in association with ADB and GoN, distribution infrastructure needed to implement electric cooking are assumed to be capable of handling the total load in domestic and non-domestic sectors.

The peak load demand is projected on the basis of energy usage and load factor. The national load factor as per NEA for 2020 and 2021 are 69% and 65% respectively. For the further analysis, the load factor is considered as 60% for other loads and for cooking load, a maximum of 50% induction stoves are assumed to be connected on the system at a time for cooking.

The peak demand needed in different years in the base case is illustrated in Figure 4.12.

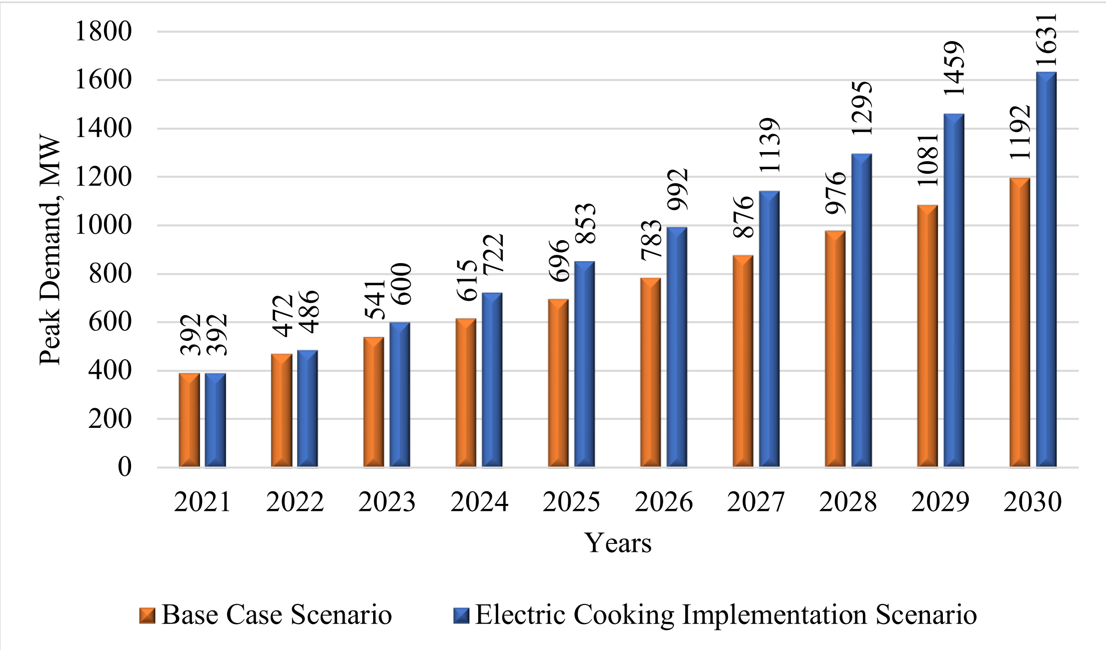

Figure 4. 12: Peak Demand in Base Case scenario and electric cooking implementation scenario

The peak demand increased to 1192 MW in 2030 from 392 MW in 2021 in the base case scenario. The demand will rise to 1631 MW in 2030 which is 36.83% higher than the base case demand.

4.4 Saving of LPG

Implementation of electric cooking will save the consumption of LPG. This research assumes that the households will shift their cooking fuel from LPG to Electricity. According to this shifting scenario, the number of households using LPG, Electricity and other fuels as primary means of cooking is calculated. By taking the fuel staking of 11.40% (LPG usage with other cooking fuels), the households using LPG are the summation of households using LPG only and households using LPG with other cooking fuels. From Figure 2. 13, the sharing of LPG consumption in Madhesh Province for year 2019 is 23.66% and for 2020 is 22.93%; we take the sharing of LPG consumption in future years as 23% of total LPG consumption of Nepal. Also, 91% of total LPG consumption in Madhesh Province is consumed in the residential sector and 68% of total LPG used in the residential sector is used for cooking purposes in 2019. Remaining 32% of LPG used in animal feed preparation and social events.

Figure 4. 13 shows the LPG consumption in base case scenario and electric cooking implementation scenario.

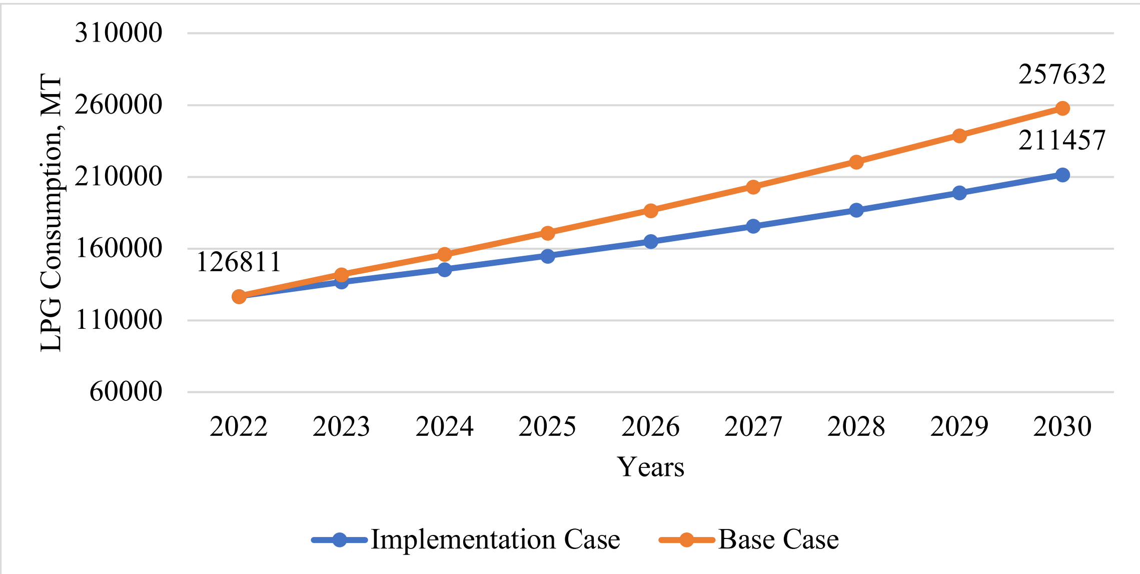

Figure 4. 13: LPG Consumption in base case scenario and electric cooking implementation scenario

As shown in Figure 4. 13 in 2030, approximately 257632 MT of LPG will be consumed in base case. The quantity of LPG will be reduced to 211457 MT in the electric cooking implementation scenario. We can reduce 17.92% of LPG consumption in 2030 by implementing electric cooking.

4.5 Optimum Penetration of electric cooking in current infrastructure

The available distribution infrastructure in Madhesh Province is given in Appendix I and II. The feeders and substation loading data are the basis for the optimum penetration level of electric cooking.

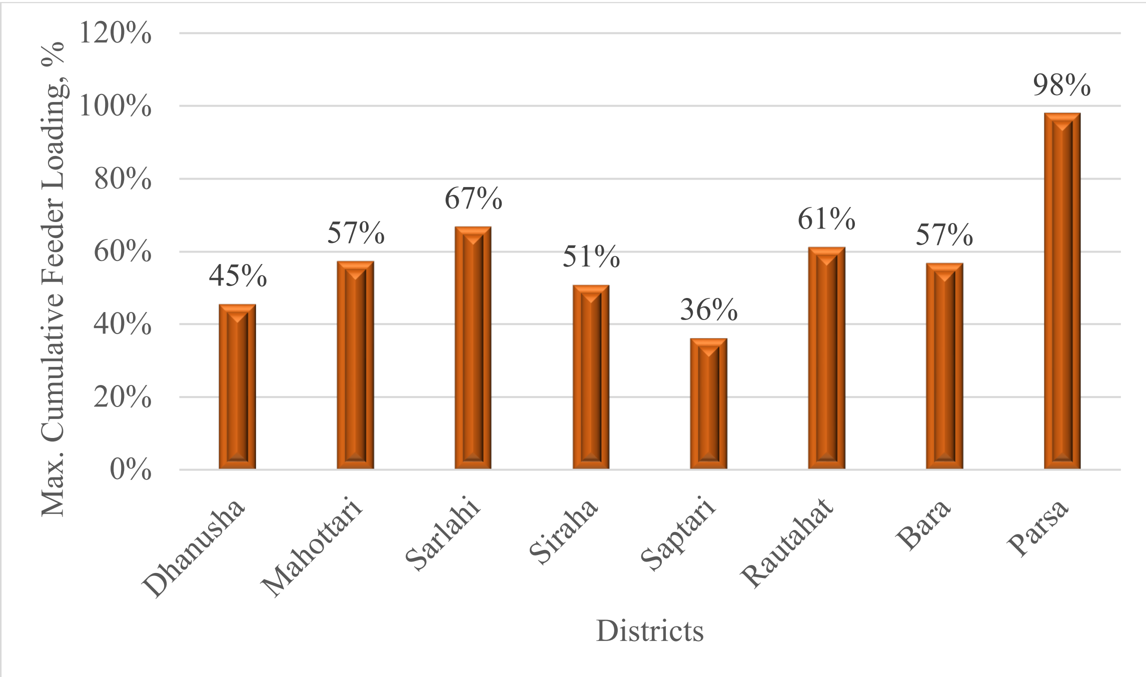

Figure 4. 14: Cumulative Maximum Feeder Loading

Figure 4. 14 shows the cumulative maximum feeder loading of different districts of Madhesh Province. As per the loading data, Parsa District has maximum feeder loading of 98% and Saptari District has lowest feeder loading of 36% considering maximum loading up to 90% of the current rating of conductor used. The implementation of electric cooking at Parsa district is not feasible in currently available feeders as per the feeder loading data. If we take Madhesh Province as a whole, 60% capacity of distribution feeder is already utilized in year 2022. For the further load addition in the feeder, the feeder should be upgraded or a new feeder should be made up to the load center to fulfill the demand.

The feeders are energized from distribution substations. There are 26 nos. of distribution substations in Madhesh Province. Figure 4. 15 shows the loading of distribution substations at Madhesh Province.

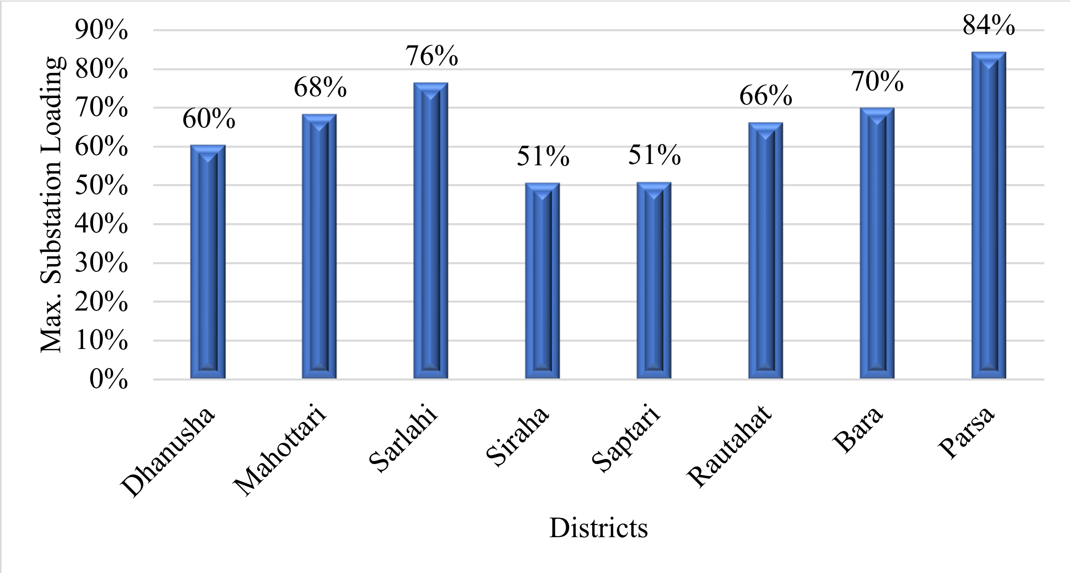

Figure 4. 15: Distribution Substation Loading at Madhesh Province

As per the figure 32, the substations at Parsa District are maximum loaded at 84% followed by Sarlahi District with 76%. Substations at Siraha and Saptari District have the loading of 51%. So, we can say that substations at Parsa district should be upgraded for the additional load to be employed. Similarly, substations at Sarlahi district should also be upgraded. In the case of the whole Madhesh Province, maximum loading of substations is 68% for year 2022.

From the loading analysis, the additional load that can be employed in the system is computed. In distribution feeders, an additional approximately maximum 273 MW of load can be added. And as per the substations loading, approximately a maximum of 197 MW of load can be connected in Madhesh Province. By taking the growth of maximum demand, the demand growth from 2022 to 2024 is 236 MW. So, the distribution infrastructure is able to supply up to the year 2024 in which electric cooking may be implemented on nearly 7% of the total households. To implement the cooking load in 25% of households, the distribution feeder and distribution substations should be added or upgraded, Also, the cooking load addition should be prioritized in Siraha, Saptari and Dhanusha Districts as the feeder loading and substation loading is less in these districts.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The study on implementation of electric cooking in Madhesh Province is done in this research. This research mainly focused on the implementation of electric cooking by taking the national target of implementing electric cooking in 25% of households up to 2030. The distribution of households using different cooking fuels for the year 2030 in the base case scenario found to be 65.15% of LPG, 2.66% of electricity and 32.17% of other cooking fuels. The distribution of households in the electric cooking implementation scenario will be 42.83% of LPG, 25% electricity and 32.17% of other cooking fuel.

The electricity needed will be 6265 GWh in 2030 in base case scenario and 6920 GWh (including distribution loss) after the implementation of electric cooking from 2229 GWh in 2021 in Madhesh Province. The electricity demand in the electric cooking implementation scenario is 10.45% more than the base case scenario.

Also, the peak demand needed in base case in 2030 is found to be 1192 MW which is 392 MW in 2021. After the electric cooking implementation, the peak demand will be 1631 MW (36.83% higher than base case scenario) in 2030.

The households using LPG will reach approximately 915,212 (65% of total households) in 2030 in the base case scenario considering the past rising trend of LPG usage in households of Madhesh Province. The share of households in the implementation case is found to be 42.83% in 2030. In base case scenario, total LPG consumption in 2030 is found to be approximately 257,632 MT which is reduced to 211,457 MT in electric cooking implementation scenario resulting in saving of 46,175 MT (18%) of LPG in 2030.

The electric cooking technologies can be implemented if the distribution infrastructures are enough to handle the increasing load demand. As per the loading data of 2022, the feeders loading is reached to 66% and distribution substation loading to 68%. By taking the allowable loading limit, electric cooking can be implemented in nearly 7% of households considering existing distribution infrastructure. Siraha, Saptari and Dhanusha are favorable for electric cooking implementation as the feeder loading and substation loading is less in these districts. Sarlahi and Parsa districts are found to be already highly loaded and the distribution system should be upgraded to employ additional load.

5.2 Recommendation

From this study it is found that the consumption of LPG can be reduced by implementing electric cooking in Madhesh Province. Since almost 100% of households have access to electricity, implementation of electric cooking can be done in existing infrastructure in the initial stage. But the existing distribution system infrastructure will not be enough to handle the increasing load demand in future. Hence to implement electric cooking, we should focus on the infrastructure so that the maximum number of households can adopt electricity as their cooking fuel.

In implementation of electric cooking, huge numbers of induction stoves will be needed. Since, fewer manufactures of induction stoves are established in Nepal; we are again dependent on import. Hence, promoting manufacturing induction stoves in Nepal could be beneficial.

To increase the electricity consumption, other applications of electricity such as promoting electric vehicles option may be studied.

References

Campo, J., & Sarmiento, V. (2013). The Relationship between energy consumption and GDP: Evidence from a Panel of 10 Latin American Countries. *Latin American Journal of Economics*, 233-255.

CBS. (2011). *National Population and Housing Census 2011 (National Report).* Kathmandu: Central Bureau of Statistics.

CBS. (2018). *ANNUAL HOUSEHOLD SURVEY.* Kathmandu: CBS.

Chhetri, R., Lham, P., & Chhetri, D. (2021). Analysis of Infrared stove, Induction Cooktop and LPG for Cooking Selective Dishes in Bhutan. *International Journal of Scientific Research and Engineering Development*, 192-197.

Committee. (2022). *Kathmandu Districts's Labour and Construction Materials Approved District rate.* District Rate Fixation Committee.

Daraz. (2023, 6 12). *Daraz*. Retrieved from Daraz: https://www.daraz.com.np/catalog/?from=filter&q=induction%20stove&sort=priceasc&style=list&rating=4&ppath=7:202300,8:4447,40048:86716,30735:20581,30720:3918

Daraz. (2023, 6 12). *Daraz*. Retrieved from Daraz: https://www.daraz.com.np/catalog/?_keyori=ss&from=input&page=2&q=induction%20cooking%20set&sort=priceasc&spm=a2a0e.searchlist.search.go.31af184dNSod9e

Daraz. (2023, July 2028). *Dazaz*. Retrieved from Daraz: https://www.daraz.com.np/catalog/?_keyori=ss&from=search_history&page=1&q=induction%20stove%20double&sort=pricedesc&spm=a2a0e.11779170.search.1.287d2d2bKvazq0&sugg=induction%20stove%20double_0_1

DCSD. (2022). *A Year book fiscal year 2079/79.* Kathmandu: Distribution and Consumer Services Directorate, Nepal Electricity Authority.

Division, C. C. (2021). *Assessment of Electric Cooking Target for Nepal's 2020 Nationally Determined Contributions (NDC).* Kathmandu: Climate Change Management Division.

ENERGIA. (2021). *Gender-Responsive Electric Cooking in Nepal.* ENERGIA International Network on Gender and Energy.

GoN. (2020). *Second Nationally Determined Contribution (NDC).* GoN.

Hahn, H., Meyer-Nieberg, S., & Pickl, S. (2009). Electric load forecasting methods: Tools for decision making. *ELSEVIER*, 902-907.

IOE, KU, NEF, & NF. (2022). *Nepal Energy Outlook 2022.* Kathmandu: IOE; KU; NEF; NF.

Jayasekara, S., & Fernando, Y. S. (2020). Reviewing the Economics of Using LPG Vs. Electricity for Household cooking in Sri Lanka. *2020 IEEE REGION 10 CONFERENCE (TENCON)*, 16-19.

NEA. (2021). Consumer Data.

NEA. (2021). Distribution Loss Data. Kathmandu.

NEA. (2021). *Nepal Electrification Status.* Kathmandu: Nepal Electricity Authority.

NEA. (2022). *A Year in Review-Fiscal Year 2021/2022.* Kathmandu: NEA.

Niraniya, D. (2023, 6 12). *Induction Stove Wattage And Power Consumption*. Retrieved from Stovepedia: https://www.stovepedia.com/blog/induction-wattage-power-consumption/

NOC. (2023, 7 29). *Import and Sales*. (NOC) Retrieved 7 29, 2023, from https://noc.org.np/import

NOC. (2023, 6 12). *LPG Prices History*. Retrieved from Nepal Oil Corporation: http://noc.org.np/lpg

NOC. (2023, 8 10). *Nepal Oil Corporation Limited*. Retrieved from https://noc.org.np/#

NSO. (2021). *National Population and Housing Census 2021 (National Report).* Kathmandu: National Statistics Office.

NSO. (2023). *National Population and Housing Census (2021) Provincial Report (Madhesh Province).* Kathmandu: National Statistics Office.

Pinto, A., Yoo, H. K., Portale, E., & Rysankova, D. (2019). *Energy Access Diagnostic Report Based on the Multi-Tier Framework.* World Bank Group.

Pokharel, S. (2004). Energy economics of cooking in households in Nepal. *ELSEVIER*, 547-559.

Pokhrel, B. (2022). *Distribution Network Performance Management for emerging load in Urban Area, Case Study of Balaju Distribution Center.*

RODRÍGUEZ, D., MARTÍNEZ-GÓMEZ, J., GUERRÓN, G., RIOFRIO, A., & Ricardo, A. N. (2019). Impact of induction stoves penetration over power quality in Ecuadorian Households. *ESPACIOS*.

Shrestha, J. N., Raut, D. B., & Shrestha, D. L. (2019). Cooking Cost Comparison using LPG, Rice Cooker, Induction Cooker and Infrared Cooker.

Sweeney, M., Dols, J., Fortenbery, B., & Sharp, F. (2014). Induction Cooking Technology Design and Assessment . *ACEEE Summer Study on Energy Efficiency in Buildings*, 9-370,9-279.

Tiandho, Y., Indriawati, A., Putri, A. K., & Afriani, F. (2020). Induction stoves: An option for clean and efficient cooking in Indonesia. *IOP Conference Series: Materials Science and Engineering*.

WECS. (2021). *Energy Consumption and Supply Situation in the Federal System of Nepal (Final Report Province 2).* Kathmandu: Water and Energy Commission Secretariat (WECS).

WECS. (2022). *Energy Sector Synopsis Report 2021/2022.* Kathmandu: WECS.

Wikimedia. (2023, 6 11). *File:Detailed Map of Madhesh Province.png*. Retrieved from Wikimedia Commons: https://commons.wikimedia.org/wiki/File:Detailed_Map_of_Madhesh_Province.png

Appendix I: Feeder Loading Data

S.No.	District	DC Name	11 kV Feeder Name	Feeder Length, km	Max Loading, 2022	Max Load, MVA	Normal/ Dedicated	Biggest Conductor Used	Conductor Size, SQ-MM	Max. Current Rating at 75^{0}C, Amp	Allowable Loading remaining	% of Loading	Normal/ Full Load/ Overload
1	Dhanusha	Yadukuwa	Dhanauji	41.49	128	2.44	N	DOG	100	291	147	44.0%	Normal
2			Sonigama	51.49	130	2.48	N	DOG	100	291	145	44.7%	Normal
3			Bhatiyan	23.92	57	1.09	N	DOG	100	291	211	19.6%	Normal
4			Kamala	28.24	56	1.07	N	DOG	100	291	212	19.2%	Normal
5		Janakpur	City 1	9.26	198	3.77	N	DOG	100	291	84	68.0%	Normal
6			City 2	12.49	246	4.69	N	DOG	100	291	41	84.5%	Normal
7			City 3	20.25	252	4.80	N	DOG	100	291	35	86.6%	Normal
8			City 4	18.24	202	3.85	N	DOG	100	291	80	69.4%	Normal
9			Piradi	51.47	202	3.85	N	DOG	100	291	80	69.4%	Normal
10			Ring	68.11	128	2.44	N	DOG	100	291	147	44.0%	Normal
11			Mahendranagar	41.21	148	2.82	N	DOG	100	291	129	50.9%	Normal
12			Industrial	6.10	120	2.29	D	DOG	100	291	154	41.2%	Normal
13			Dedicated	8.03	124	2.36	D	DOG	100	291	150	42.6%	Normal
14		Sakhuwa	Mahendranagar	164.00	228	4.34	N	DOG	100	291	57	78.4%	Normal
15			Lalgadh	70.00	210	4.00	N	DOG	100	291	73	72.2%	Normal
16			Godar	65.00	85	1.62	N	DOG	100	291	185	29.2%	Normal
17			Dhalkebar	5.00	24	0.46	N	DOG	100	291	240	8.2%	Normal
18			Kishanpur	14.93	61	1.16	N	DOG	100	291	207	21.0%	Normal
19			Industrial	16.00	30	0.57	D	DOG	100	291	235	10.3%	Normal
20		Dhanusadham	Sabaila	21.06	90	1.71	N	DOG	100	291	181	30.9%	Normal
21			Dhanushadham	23.43	60	1.14	N	DOG	100	291	208	20.6%	Normal
22			Kisanpur	34.04	73	1.39	N	DOG	100	291	196	25.1%	Normal
23			Hanspur	23.94	45	0.86	N	DOG	100	291	221	15.5%	Normal
24			Godal Old	82.00	52	1.00	N	DOG	100	291	215	18.0%	Normal
25			Godar New	10.00	117	2.23	N	DOG	100	291	157	40.2%	Normal
26			Mahendranagar	26.20	27	0.51	N	DOG	100	291	238	9.3%	Normal
27	Mahottari	Jaleshwor	City	15.00	85	1.62	N	RABBIT	50	190	95	44.7%	Normal
28			Ring	10.00	17	0.32	N	RABBIT	50	190	156	8.9%	Normal
29			Pipra	61.00	155	2.95	N	RABBIT	50	190	32	81.6%	Normal
30			Mathihani	60.54	125	2.38	N	RABBIT	50	190	59	65.8%	Normal
31			Katti	55.00	120	2.29	N	RABBIT	50	190	63	63.2%	Normal
32			Ekdara	45.00	90	1.71	N	RABBIT	50	190	90	47.4%	Normal
33			Loharpatti	65.00	145	2.76	N	RABBIT	50	190	41	76.3%	Normal
34			Paraul	59.50	140	2.67	N	RABBIT	50	190	45	73.7%	Normal
35		Gaushala	Gaushala	50.13	132	2.51	N	RABBIT	50	190	52	69.5%	Normal

36			Bharatpur	75.91	158	3.01	N	DOG	100	291	120	54.3%	Normal
37			Sonamai	54.68	129	2.46	N	RAB BIT	50	190	55	67.9%	Normal
38			Bhangaha	43.50	133	2.53	N	RAB BIT	50	190	51	70.0%	Normal
39			Aurhi	56.43	259	4.93	N	DOG	100	291	29	89.0%	Normal
40			Lalgadh	70.00	92	1.75	N	DOG	100	291	179	31.6%	Normal
41			Bazar	19.64	21	0.40	N	DOG	100	291	243	7.2%	Normal
42			Bharattole	3.16	27	0.51	N	DOG	100	291	238	9.3%	Normal
43			Malangwa	33.05	164	3.12	N	DOG	100	291	114	56.4%	Normal
44		Malangwa	Gramin	185.85	188	3.58	N	DOG	100	291	93	64.6%	Normal
45			Kaudena	259.60	329	6.27	N	DOG	100	291	0	113.1%	Overload
46			Chameli Mai	50.05	135	2.57	N	DOG	100	291	140	46.4%	Normal
47			Barahathwa	42.00	249	4.74	N	DOG	100	291	38	85.6%	Normal
48	Sarlahi	Barahathwa	Hirapur	63.50	90	1.71	N	DOG	100	291	181	30.9%	Normal
49			Soltee	20.20	53	1.01	N	DOG	100	291	214	18.2%	Normal
50			Lalbandi	126.00	200	3.81	N	DOG	100	291	82	68.7%	Normal
51		Lalbandi	Harion	111.50	210	4.00	N	DOG	100	291	73	72.2%	Normal
52			Gair	25.00	75	1.43	N	DOG	100	291	194	25.8%	Normal
53			Pangachhiya	66.00	230	4.38	N	DOG	100	291	55	79.0%	Normal
54			Thadi	87.27	202	3.85	N	DOG	100	291	80	69.4%	Normal
55			Lahan	71.09	215	4.10	N	DOG	100	291	68	73.9%	Normal
56		Lahan	Sitapur	59.23	151	2.88	N	DOG	100	291	126	51.9%	Normal
57			Jahadi	192.96	271	5.16	N	DOG	100	291	0	93.1%	Full Load
58			Bastipur	118.11	66	1.26	N	DOG	100	291	203	22.7%	Normal
59			Siraha	80.19	144	2.74	N	DOG	100	291	132	49.5%	Normal
60	Siraha	Siraha	Bishnupur	49.03	96	1.83	N	DOG	100	291	176	33.0%	Normal
61			Kalyanpur	72.49	108	2.06	N	DOG	100	291	165	37.1%	Normal
62			Aurhi	30.99	102	1.94	N	DOG	100	291	170	35.1%	Normal
63			Bandipur	45.14	158	3.01	N	DOG	100	291	120	54.3%	Normal
64		Mirchaiya	Mirchaiya	30.80	59	1.12	N	DOG	100	291	209	20.3%	Normal
65			Kalyanpur	27.87	77	1.47	N	DOG	100	291	193	26.5%	Normal
66			Golbazar	101.50	80	1.52	N	DOG	100	291	190	27.5%	Normal
67			Bazar-1	5.18	143	2.72	N	DOG	100	291	133	49.1%	Normal
68			Bazar-2	17.20	155	2.95	N	DOG	100	291	122	53.3%	Normal
69			Paschim Gramin	75.65	190	3.62	N	DOG	100	291	91	65.3%	Normal
70			Daschin Gramin	51.46	115	2.19	N	DOG	100	291	158	39.5%	Normal
71			Purbi Gramin	55.74	145	2.76	N	DOG	100	291	131	49.8%	Normal
72		Rajbiraj	Raypur	22.77	42	0.80	N	DOG	100	291	224	14.4%	Normal
73	Saptari		Hospital	0.79	13	0.24	N	DOG	100	291	251	4.3%	Normal
74			Kalyanpur	28.52	58	1.11	N	DOG	100	291	210	19.9%	Normal
75			Rupani Raypur	12.16	29	0.55	N	DOG	100	291	236	10.0%	Normal
76			Rupani Purbi	6.37	85	1.62	N	DOG	100	291	185	29.2%	Normal
77			Industrial	6.60	16	0.30	D	DOG	100	291	248	5.5%	Normal
78			Hanumannagar	15.06	26	0.50	N	DOG	100	291	239	8.9%	Normal
79		Kanchanpur	Kanchanpur	29.00	90	1.71	N	DOG	100	291	181	30.9%	Normal
80			Hanumannagar	8.00	62	1.18	N	DOG	100	291	206	21.3%	Normal

81			Kanchanpur	46.42	185	3.52	N	DOG	100	291	95	63.6%	Normal
82			Rupni Purvi	22.00	65	1.24	N	DOG	100	291	203	22.3%	Normal
83			Rajbiraj Purvi	12.00	115	2.19	N	DOG	100	291	158	39.5%	Normal
84			Bodebarsain	60.00	99	1.89	N	DOG	100	291	173	34.0%	Normal
85			Manraja	24.00	62	1.18	N	DOG	100	291	206	21.3%	Normal
86		Bodebarsain	Mahubelhi	0.00			N			0			Normal
87			Paschim Gramin	95.00	200	3.81	N	DOG	100	291	82	68.7%	Normal
88			Gaur	15.00	250	4.76	N	DOG	100	291	37	85.9%	Normal
89			Bahuarwa	79.43	240	4.57	N	DOG	100	291	46	82.5%	Normal
90		Gaur	Bairiya	71.19	240	4.57	N	DOG	100	291	46	82.5%	Normal
91			Puenwa	30.00	120	2.29	N	DOG	100	291	154	41.2%	Normal
92			Bankul	114.10	95	1.81	N	DOG	100	291	176	32.6%	Normal
93			Harsaha	165.88	210	4.00	N	DOG	100	291	73	72.2%	Normal
94			Bankul	12.00	40	0.76	N	DOG	100	291	226	13.7%	Normal
95	Rauta hat		Maulapur	32.00	155	2.95	N	DOG	100	291	122	53.3%	Normal
96		Maulapur	Baudhimai	20.00	135	2.57	N	DOG	100	291	140	46.4%	Normal
97			Katahariya	53.78	147	2.80	N	DOG	100	291	130	50.5%	Normal
98			Chandranigahapur North	44.75	165	3.14	N	DOG	100	291	113	56.7%	Normal
99		Chandranigahapur	Chandranigahapur South	99.79	194	3.70	N	DOG	100	291	87	66.7%	Normal
100			Chandranigahapur Harsawa	28.59	109	2.08	N	DOG	100	291	164	37.5%	Normal
101			Jagalsahiya	40.00	143	2.72	N	DOG	100	291	133	49.1%	Normal
102			Hulash	13.00	155	2.95	D	DOG	100	291	122	53.3%	Normal
103			Jeetpur	4.00	259	4.93	N	DOG	100	291	29	89.0%	Normal
104			Dumrawana	36.00	219	4.17	N	DOG	100	291	65	75.3%	Normal
105			Narbasti	10.00	235	4.48	N	DOG	100	291	50	80.8%	Normal
106			Musarnimai	2.00	233	4.44	N	DOG	100	291	52	80.1%	Normal
107			Ramban	68.39	141	2.69	N	DOG	100	291	135	48.5%	Normal
108			Airport Dedicated	1.50	6	0.11	D	WEASWEL	30	138	119	4.3%	Normal
109			Nijgadh 1	39.00	75	1.43	N	DOG	100	291	194	25.8%	Normal
110			Nijgadh 2	10.00	70	1.33	N	DOG	100	291	199	24.1%	Normal
111		Simara	Nijgadh 3	21.00	65	1.24	N	DOG	100	291	203	22.3%	Normal
112			Parwanipur	17.00	440	8.38	N	DOG	100	291	0	151.2%	Overload
113	Bara		Simara	7.00	360	6.86	N	DOG	100	291	0	123.7%	Overload
114			Pathlaiya-1	17.00	297	5.66	N	DOG	100	291	0	102.1%	Overload
115			Pathlaiya-2	13.00	110	2.10	N	DOG	100	291	163	37.8%	Normal
116			Piluwa	9.00	45	0.86	N	DOG	100	291	221	15.5%	Normal
117			Amlekhgunj	23.00	40	0.76	N	DOG	100	291	226	13.7%	Normal
118			Oil Nigam	1.30	22	0.42	D	DOG	100	291	242	7.6%	Normal
119			Pole Plant	0.30	8	0.15	D	WEASWEL	30	138	117	5.8%	Normal
120			Chhapkiya	7.89	21	0.40	N	DOG	100	291	243	7.2%	Normal
121			Nagarpalika	22.29	180	3.43	N	DOG	100	291	100	61.9%	Normal
122		Kalaiya	Ganjbhawanipur	84.15	190	3.62	N	DOG	100	291	91	65.3%	Normal
123			Bariyarpur	54.36	140	2.67	N	DOG	100	291	136	48.1%	Normal
124			Inarwasira	74.87	230	4.38	N	DOG	100	291	55	79.0%	Normal

125			Shitalpur	21.51	65	1.24	N	DOG	100	291	203	22.3%	Normal
126			Rampur	7.86	105	2.00	N	DOG	100	291	167	36.1%	Normal
127			Badharwa	49.44	80	1.52	N	DOG	100	291	190	27.5%	Normal
128			Krishi	67.87	240	4.57	N	RAB BIT	50	190	0	126.3%	Overload
129			Simarungadh Bazar	33.69	136	2.59	N	DOG	100	291	140	46.7%	Normal
130			Barta	25.00	91	1.73	N	DOG	100	291	180	31.3%	Normal
131		Simroungardh	Pachrauta	56.12	212	4.04	N	DOG	100	291	71	72.9%	Normal
132			Bariyarpur	17.49	34	0.65	N	DOG	100	291	231	11.7%	Normal
133			Sitapur	20.20	43	0.82	N	DOG	100	291	223	14.8%	Normal
134			Pokhariya	62.68	75	1.43	N	DOG	100	291	194	25.8%	Normal
135			Janki Tole	50.00	65	1.24	N	DOG	100	291	203	22.3%	Normal
136			Langadi	68.60	73	1.39	N	DOG	100	291	196	25.1%	Normal
137			6 No	93.46	285	5.43	N	DOG	100	291	0	97.9%	Full Load
138			Gramin	5.30	125	2.38	N	RAB BIT	50	190	59	65.8%	Normal
139		Pokhariya	Ramban	3.20	62	1.18	N	RAB BIT	50	190	115	32.6%	Normal
140			Bindabasini	15.00	310	5.91	N	RAB BIT	50	190	0	163.2%	Overload
141			Jankitola	21.31	27	0.51	N	RAB BIT	50	190	147	14.2%	Normal
142			Latomai	10.00	7	0.13	N	RAB BIT	50	190	165	3.7%	Normal
143			Thori	41.31	18	0.34	N	RAB BIT	50	190	155	9.5%	Normal
144			Birgunj 1	14.56	370	7.05	N	DOG	100	291	0	127.1%	Overload
145			Birgunj 2	21.58	289	5.51	N	DOG	100	291	0	99.3%	Full Load
146			Birgunj 4	27.58	318	6.06	N	DOG	100	291	0	109.3%	Overload
147			Birgunj 5	14.22	355	6.76	N	DOG	100	291	0	122.0%	Overload
148	Parsa		Birgunj 6	21.52	299	5.70	N	DOG	100	291	0	102.7%	Overload
149			Parasauni	16.10	316	6.02	N	DOG	100	291	0	108.6%	Overload
150			Bindawasini	14.08	301	5.73	N	DOG	100	291	0	103.4%	Overload
151			Jagarnathpur	6.50	351	6.69	N	DOG	100	291	0	120.6%	Overload
152			Narayani	4.28	260	4.95	D	DOG	100	291	28	89.3%	Normal
153			Himal	9.10	280	5.33	D	DOG	100	291	0	96.2%	Full Load
154		Birgunj	Chorni	4.89	309	5.89	N	DOG	100	291	0	106.2%	Overload
155			Gramin	25.45	213	4.06	N	DOG	100	291	70	73.2%	Normal
156			Birgunj Industrial	10.61	216	4.12	D	DOG	100	291	68	74.2%	Normal
157			Dawar Nepal	1.43	210	4.00	D	DOG	100	291	73	72.2%	Normal
158			Gandak	14.89	310	5.91	N	DOG	100	291	0	106.5%	Overload
159			Nitapur	13.90	360	6.86	N	DOG	100	291	0	123.7%	Overload
160			Krishi	17.06	240	4.57	N	DOG	100	291	46	82.5%	Normal
161			Parwanipur	7.67	410	7.81	N	DOG	100	291	0	140.9%	Overload
162			Jagadamba	6.92	320	6.10	D	DOG	100	291	0	110.0%	Overload
163			Simara Feeder	9.65	327	6.23	N	DOG	100	291	0	112.4%	Overload
164			Valuwi	5.67	310	5.91	N	DOG	100	291	0	106.5%	Overload

N= Normal

D= Dedicated

Appendix II: Substation Loading Data

Madhesh Province: Grid Substation Loading Status, F/Y 2078/79								
S.No.	Substation Name	Voltage Level, kV/kV	Nos. of Transformers	Capacity, MVA	Total Capacity, MVA	Maximum Loading, MVA	% Loading	Remarks
1	Birgunj	66/33	1	30	30	23.21	77.35%	
		66/33	1	12.5	12.5	11.09	88.71%	
		66/11	2	30	60	27.43	91.45%	
		66/11		30		23.09	76.97%	
2	Parwanipur	132/11	3	22.5	67.5	19.66	87.39%	
		132/11		22.5		19.66	87.39%	
		132/11		22.5		19.66	87.39%	
		132/66	3	63	189	59.44	94.35%	
		132/66		63		59.44	94.35%	
		132/66		63		59.44	94.35%	
3	Simra	66/11	2	15	30	12.07	80.48%	
		66/11		15		5.38	35.89%	
4	Amlekhgunj	66/11	1	7.5	7.5	0.80	10.67%	
5	Pathalaiya	132/11	1	22.5	22.5	3.90	17.31%	
6	Lahan	132/33	1	63	63	38.87	61.69%	
		132/33	1	63	63	0.00	0.00%	
		33/11	2	16.6	33.2	5.28	31.79%	
		33/11		16.6		10.35	62.32%	
7	Mirchaiya	132/33	1	30	30	21.95	73.16%	
8	Dhalkebar	132/33	1	63	126	28.81	45.72%	
		132/33	1	63		61.27	97.26%	
		33/11	2	16.6	33.2	10.46	63.01%	
		33/11		16.6		10.29	61.98%	
9	Chapur	132/33	2	30	60	29.26	97.55%	
		132/33		30		29.26	97.55%	
		33/11	1	16.6	16.6	5.60	33.74%	
10	400kV SAS	400/220	3	315	945	147.43	46.80%	
		400/220		315		145.94	46.33%	
		400/220		315		145.73	46.26%	
		220/132	2	315	630	186.64	59.25%	
		220/132		315		89.56	28.43%	
		220/132	2	160	320	161.87	101.17%	
		220/132		160		163.58	102.24%	
11	Rupani	132/33	1	63	63	27.89	44.27%	
Overall Loading					**2802**	**1664.31**	**59.40%**	
33kV Distribution Side Loading					**447.5**	**300.87**	**67.23%**	
11 kV Distribution Side Loading					**270.5**	**173.63**	**64.19%**	
					718	475	66%	

Loading data as of F/Y 2022

District	DC Name	DC SS Name	Voltage Level	Capacity, MVA	Grid SS Name	Voltage Level	Capacity, MVA	Total Capacity, MVA	District's Total Installed Capacity of Substations, MVA	Total Grid Transformer Max. Loading(11 kV), MVA	Total Max. Load, MVA	Max. Load/SS Capacity
Dhanusha	Janakpur	Mujeliya	33/11	40	Dhalkebar	33/11	33.2	73.2	97.8	20.75	58.94	60.26%
	Yadukuwa	Yadukuwa	33/11	8				8				
	Dhanushadham	Dhanushadham	33/11	16.6				16.6				
Mahottari	Jaleshwor	Jaleshwor	33/11	16				16	51		34.83	68.29%
		Paraul	33/11	8				8				
		Aurahi	33/11	24				24				
	Gaushala	Khairmara	33/11	3				3				
Sarlahi	Malangwa	Malagnwa	33/11	16				16	48		36.64	76.33%
	Barahathwa	Barahathwa	33/11	8				8				
	Lalbandi	Haripur	33/11	24				24				
Siraha	Siraha	Bishnupur	33/11	16	Lahan	33/11	33.2	49.2	65.2	15.62	32.94	50.52%
	Mirchaiya	Mirchaiya	33/11	16				16				
Saptari	Rajbiraj	Rajbiraj	33/11	24.5				24.5	71.1		36.10	50.77%
		Rupani	33/11	19.6				19.6				
	Bodebarsain	Bodebarsain	33/11	8				8				
	Kanchanpur	Bhardaha	33/11	11				11				
		Balardah	33/11	8				8				
Rautahat	Maulapur	Maulapur	33/11	8	Chapur	33/11	16.6	24.6	64.6	5.60	42.73	66.15%
	Gaur	Gaur	33/11	16				16				
		Harshaha	33/11	24				24				
Bara	Simara	Nijhgadh	33/11	8	Simara	66/11	30	38	124	17.46	86.63	69.86%
	Kalaiya	Kalaiya	33/11	32	Amlekggunj	66/11	7.5	39.5		0.80		
	Simraungadh	Simraungadh	33/11	24	Pathalaiya	132/11	22.5	46.5		3.90		
Parsa	Birgunj	Chapkiya	33/11	8	Birgunj	66/11	60	68	167.5	50.53	141.20	84.30%
	Pokhariya	Pokhariya	33/11	24	Parwanipur	132/11	67.5	91.5		58.98		
		Seduwa	33/11	8				8				
				419			271	689	689	174	470	

Appendix III: LPG Sales Data (Nepal)

LPG Sales

Fiscal Year	LPG IN MT
2067/068 (2010/2011 AD)	159286
2068/069(2011/2012 AD)	181411
2069/2070 (2012/2013 AD)	207038
2072/73(2015-16AD)	214194
2070/71 (2013-14AD)	232660
2071/72 (2014-15AD)	258299
2073/74(2016-17AD)	312928
2074/75 (2017-18AD)	370560
2075/76 (2018-19AD)	429609
2076/77 (2019-20AD)	449063
2077/78 (2020-21AD)	477752
2078/79 (2021-22AD)	536028

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