Government of Nepal
Water and Energy Commission Secretariat
Singhdurbar, Kathmandu

A REPORT ON:

Present Status and Future Plan of Clean Cooking Technologies in Major Cities of Nepal (Biratnagar Metropolitan City)

June, 2024

EXECUTIVE SUMMARY

Nepal possesses abundant clean energy resources that offer significant potential for environmentally friendly cooking solutions in both residential and commercial sectors. However, the predominant energy sources for cooking have been traditional fuelwood and Liquefied Petroleum Gas (LPG). According to the Nepal Population and Housing Census 2021, approximately 51% of households rely on fuelwood, while 44% use LPG. In urban areas, LPG is the primary cooking fuel, whereas fuelwood is more prevalent in rural regions. This study evaluates the current cooking practices and explores the potential for adopting clean cooking technologies in Biratnagar Metropolitan City.

The study employs a sample survey-based methodology to understand energy usage trends in Biratnagar's residential and commercial sectors. Using Krejci and Morgan's formula, a sample size at 95% confidence level, 5% margin of error and 5% non-response rate was determined for residential and commercial sector. Households served as sample units in the residential sector, while commercial entities were the sample units in the commercial sector. Consequently, 408 household samples from various wards in the residential sector and 351 samples in the commercial sector were surveyed. Data collection involved key informant interviews focusing on socioeconomic status, current cooking practices, willingness to adopt alternative methods, barriers faced, and indoor air quality concerns. The data collection provided insights into baseline energy consumption for cooking, forming the basis for analyzing the feasibility of transitioning to cleaner cooking technologies. To forecast energy demand within the residential and commercial sectors, service demand projection in two scenarios namely, a business-as-usual scenario and a shifting scenario were employed. These scenarios were formulated based on historical trends and governmental plans and policies, and consequently, the energy demand was forecasted accordingly.

The energy survey in the residential sector of Biratnagar Metropolitan City revealed that a vast majority of households, 99.75%, rely on LPG stoves for cooking. Additionally, 12.75% of households use biomass cookstoves, while 12.99% use rice cookers. Electric cook stoves, primarily induction cook stoves, are utilized by 9.07% of households. It was also observed that 30.14% of households use more than one type of stove, with a combination of LPG and fuelwood being the most common. In term of fuels, 20.34% of households use electricity, 12.01% use fuelwood, and 0.74%, use dung cakes. The total energy demand of residential sector of Biratnagar is found to be 515.28 TJ with majority share of LPG.

In the commercial sector, all entities use LPG as their primary cooking fuel. Additionally, there is a notable presence of electric cook stoves, used by 15.38% of commercial entities. Other cooking methods in this sector include rice cookers, which are used by 39.32% of entities, biomass-based stoves used by 2.28%, and furnaces, which are used by 0.57%. The total energy demand of commercial sectors of Biratnagar in the year 2024 is found to be 90.05 TJ. These insights reflect the current dependence on LPG across both residential and commercial sectors, with a growing interest in electric cooking options, particularly in commercial establishments. The data highlights the potential for increased adoption of cleaner cooking technologies if appropriate infrastructure, financial incentives, and policy support are provided.

The study highlights a significant reliance on LPG for cooking in Biratnagar, with a notable interest in shifting towards electricity due to its higher efficiency. Most residential households find their current cooking technology convenient but expensive, likely due to the high cost of LPG. In the commercial sector, time and space efficiency are major concerns. The primary barriers to adopting clean cooking technologies include current fuse ratings, with many households and commercial entities still using 6A fuses. Upgrading to at least 16A fuses and improving transmission and distribution lines are essential. Financial incentives, such as reductions in Value-Added Tax (VAT) and customs duty, could further motivate consumers to adopt cleaner energy sources for cooking.

Two scenarios were developed to predict future energy demand: Business as Usual (BAU) and a Shifting Scenario aligned with Nepal's Long-term Strategy for Net Zero Emission. The service demand projection model was utilized to project energy demand for cooking in Biratnagar up to 2050, with forecasts presented at five-year intervals. The energy demand of residential sectors is predicted to become 922.37 TJ in year 2050 while the energy demand of commercial sectors is predicted to be 249.72 TJ by 2050 under the BAU scenario. Similarly, in shifting scenario, the energy demand of residential sectors is predicted to become 474.60 TJ while that of commercial sectors is predicted to become 142.24 TJ.

The study recommends upgrading infrastructure, including fuse ratings to at least 16A and enhancing transmission and distribution lines. It also suggests financial incentives such as reducing VAT and customs duty to encourage clean energy adoption. Additionally, public awareness campaigns and training programs are essential to educate consumers about the benefits of clean cooking technologies. Strengthening policy support is crucial to promote these technologies and align with Nepal's long-term emission reduction targets, creating a conducive environment for innovation and investment in clean energy solutions. For this, the federal, provincial and local government needs to make strong action plans and make effective implementation to ensure effectiveness and reliability of clean cooking technologies. This study underscores the urgent need for a strategic shift towards clean cooking technologies in Biratnagar to enhance energy efficiency, reduce greenhouse gas emissions, and improve indoor air quality. By addressing the identified barriers and implementing the recommended measures, Biratnagar can significantly advance its clean energy initiatives and contribute to Nepal's broader environmental and economic goals.

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LIST OF ABBREVIATIONS

ALCC	Annual Life Cycle Cost
AF	Adaptation Fund
BAU	Business as Usual
CBS	Central Bureau of Statistics
CCS	Clean Cooking Solution
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GESI	Gender Equality and Social Inclusion
GHG	Greenhouse Gases
ICS	Improved Cook Stoves
IAP	Indoor Air Pollution
kWh	Kilowatt Hour
LCC	Life Cycle Cost
LDCF	Least Developed Countries Fund
LEAP	Low Emission Analysis Platform
LPG	Liquefied Petroleum Gas
MTF	Multi-tier Framework
MW	Mega Watt
NAP	National Adaptation Plan
NDC	Nationally Determined Contribution
NSIC	Nepal Standard Industrial Classification
SCCF	Special Climate Change Fund
SDG	Sustainable Development Goal
SPSS	Statistical Package for Social Science
SWOT	Strengths Weaknesses Opportunities Threats
ToR	Term of Reference
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER ONE: INTRODUCTION

1.1 Background

Nepal's energy sector is widely recognized as being the key driver to the nation's future economic growth. Nepal has an abundance of resources for clean energy generation; Nepal has targeted 100% electrification status by 2030, along with increasing resilience through the promotion of clean fuels and technology while decreasing dependence on solid and traditional fuels. As a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, Nepal pursues and supports efforts to limit average global temperature rise to 1.5°C above pre-industrial levels. Nepal has committed to achieve net zero carbon emission through various strategic actions. These include the promotion of clean cooking technologies within the residential sector and total electrification within the commercial sector (Ministry of Forests and Environment, 2021). Similarly, Nepal has further committed in its second Nationally Determined Contribution (NDC), to reduce 23% reductions in emissions as compared to the business as usual (BAU) scenario by promoting clean cooking technologies (Ministry of Forests and Environment, 2020).

However, Nepal faces significant challenges in cleaning its cooking sector with more than 54% of the households still dependent on traditional fuel for cooking (WECS, 2023). Additionally, most of the household use inefficient traditional cookstoves which not only uses substantially more energy than required but also emits huge amount of Green House Gases (GHG) emissions and indoor pollutants. Additionally, the increasing demand of Liquefied Petroleum Gas (LPG), an imported fossil fuels, especially in urban areas is continuously increasing the trade deficit thus exposing Nepal to the economic and energy security risks. Hence, proper energy planning is of paramount importance for penetrating clean cooking technologies while also achieving Nepal's goal and target.

Water and Energy Commission Secretariat (WECS) with the objective of assisting the government of Nepal in preparing different planning and policies has been preparing the baseline of energy consumption in different economic sectors. WECS has previously conducted energy survey in different local levels, districts provinces and economic sector to access the energy demand and supply and accordingly project the energy demand using various econometric model. WECS has also previously conducted the assignment to access the energy demand for cooking in Pokhara Metropolitan City, Butwal Metropolitan City and Kathmandu Valley. These studies focused identifying the share of different fuels and technologies, energy consumption and barriers and hindrance for transition to clean cooking and energy forecast in different shifting scenario. To continue this trend of study, WECS is conducting a study on the cooking practices in Biratnagar Metropolitan City to gather valuable insights.

1.2 Objectives

The main objective of the assignment was to assess the current status of cooking technologies and devise a plan for transitioning to cleaner cooking technologies in Biratnagar Metropolitan City. The specific objectives include:

- To find out the present status of different cooking technologies used in the residential and commercial sectors
- To find out the future possibilities of switching to cleaner versions of cooking technologies
- To calculate and compare the costs i.e. base cost running cost and emission of different cooking fuel resources and technologies
- To find out the constraints and barriers to switching to cleaner forms of cooking technologies
- To recommend the policy briefs for decision makers/planners

1.3 Scope of work

The assignment has been carried out systematically using appropriate methods and methodology in Biratnagar. The scope of work included:

- Review of different plans, policies, and documents prepared by the institutions within the country and delivery partners related to the assignment
- Preparation of a detailed questionnaire for the residential and commercial sector in consultation with WECS
- Determination of sample size at a 95% level of confidence, 5% margin error, and a 5% non-response rate for different economic sector
- Conduction of energy survey to collect basic socioeconomic information and information related to cooking technologies and fuels
- Assessment of future possibilities and willingness to switch to clean cooking technologies
- Gap analysis to identify the barriers and constraints in switching to cleaner forms of technologies
- Identification of the cost and emission parameters related to different cooking technologies and cooking fuel resources
- Calculation of the energy demand for various scenarios for different cooking technologies with BAU and switching of technologies for the upcoming 15 years in a 5-year step
- Setting of benchmark the technical requirement for the use of electric cooking technologies and accordingly developing the investment cost to shift to clean cooking technologies
- Develop a policy brief and incorporate it into the final report

1.4 Limitations of the study

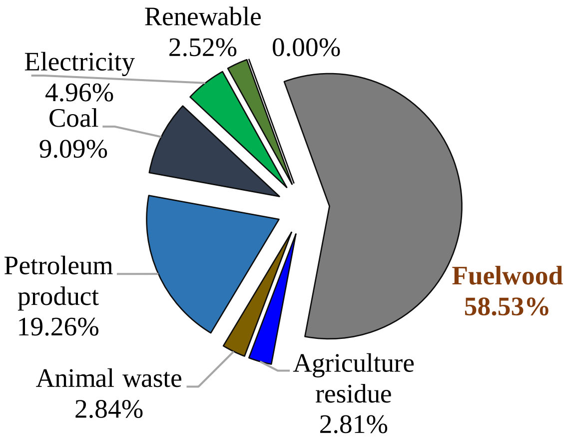
Although a comprehensive study was undertaken to determine the study's outputs, there were certain limitations that arose during the research. These limitations include:

- Study considers carbon dioxide (CO_2), methane (CH_4) & nitrous oxide (N_2O) as GHG emissions
- Electrical equipment used for water boiling, mixing, grinding, e-cookers and air fryers have not been considered cooking technology.

CHAPTER TWO: LITERATURE REVIEW

2.1 Nepal's energy landscape

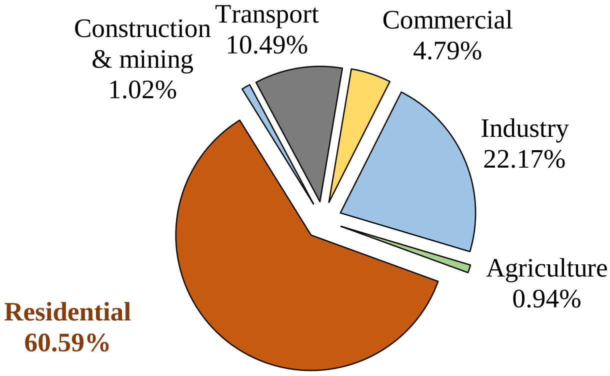
Nepal's total energy consumption in 2022 was 640 PJ and has increased at a Compound Annual Growth Rate (CAGR) of 3.44% since 2009 (WECS, 2023). Due to the lack of fossil fuel reserves, primary energy mostly depends on biomass such as fuelwood. Fuelwood comprises 58.53% of the total energy, followed by petroleum products (19.26%). The overall energy consumption segregated by fuel use in Nepal is shown in Figure 2.1.



(WECS, 2023)

Figure 2.1: Share of fuels in energy consumption

Similarly, in 2022, the residential sector consumed the highest share of energy at 60.59%, followed by industrial, transportation, commercial, and other sectors, which have been estimated to be 22.17%, 10.49%, 4.79%, and 1.96%, respectively. The large share of energy consumption in the residential sector is due to biomass burning for cooking and space heating.



(WECS, 2023)

Figure 2.2: Sectoral energy consumption

Nepal has set its goal to achieve net zero emissions by 2045. However, the energy sector GHG emissions in 2019 was 17.18 CO_{2eq} as shown in Table 2.1. In Nepal, the residential sector contributes to the majority of the emissions followed by the transportation sector. The emission from transport sector is reported to be 5.15 CO_{2eq}. Increasing electrification in the transport sector would help to curb out a major portion of GHG emissions in Nepal.

Table 2.1: Emissions in Nepal from energy sector 2019

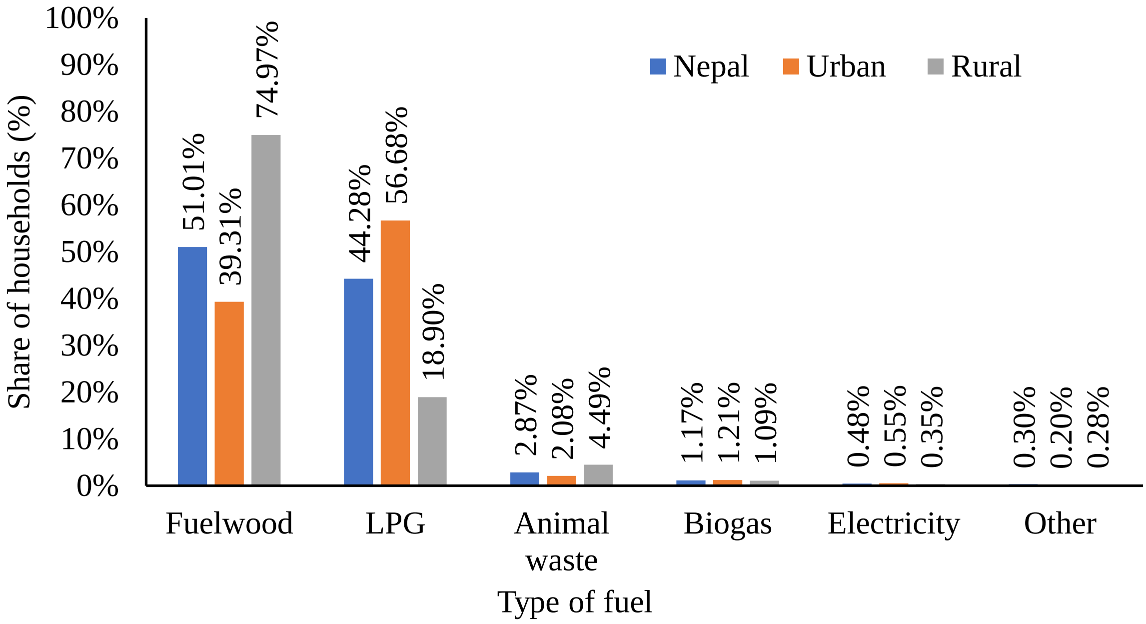
(Million metric tonnes)

Sectors	Methane (CH_4)	Nitrous oxide (N_2O)	Carbon dioxide (CO_2)	CO_2 equivalent
Residential	0.41	3.57	2.09	6.07
Transport	0.40	0.01	4.73	5.15
Industrial	0.02	0.02	4.45	4.49
Commercial	0.01	0.13	0.54	0.69
Agricultural	0.00	0.00	0.78	0.78
Total	0.85	3.74	12.59	17.18

(Ministry of Forests and Environment, 2021)

2.2 Status of cooking fuels and technology

The Nepal Population and Housing Census 2021 highlights that 51.01% and 44.28% of households use fuelwood and LPG as their primary cooking fuels, respectively. Similarly, 56.68% of households in urban areas depend on LPG as their primary fuel for cooking, while 39.31% are dependent on fuelwood. Similarly, in rural areas, 74.97% of households are dependent on fuelwood as their primary source of cooking, as shown in Figure 2.3.



(CBS, 2022)

Figure 2.3: Energy consumption by fuel types in 2021

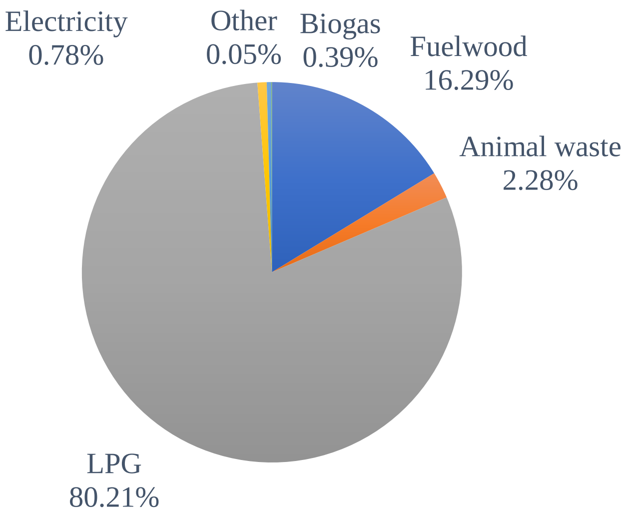
Similarly, Energy Consumption and Supply Situation in the federal system of Nepal, 2021 for Koshi Province presents the energy consumption for cooking in Morang District. The report highlight that the total energy consumption for cooking in residential sector in urban areas of Morang District was 2.05 PJ with fuelwood as major source of energy. Similarly, the report further highlights that the total energy used for cooking in commercial sector is 193.54 TJ with LPG as major source of energy as shown in Figure 2.2.

Table 2.2: Energy consumption for cooking in Morang District

Sector	Energy consumption (TJ)					
	Fuelwood	Animal waste	LPG	Electricity	Biogas	Total
Residential sector	911.2	434.68	690.8	4.26	9.11	2,050.05
Commercial sector	62.22		130.86	0.43		193.51
Total	973.42	434.68	821.66	4.69	9.11	2,243.56

(WECS, 2021)

Similarly, the Nepal Population and Housing Census 2021 further identifies the primary source of cooking fuels in Biratnagar Metropolitan City. The data reveals that LPG is the predominant cooking fuel choice for Biratnagar households, followed by fuelwood at 16.29%. Figure 2.4 illustrates the distribution of primary cooking fuel sources among Biratnagar.



(CBS, 2022)

Figure 2.4: Primary cooking fuels in Biratnagar

2.3 Clean cooking technologies and fuels

According to the World Health Organization (WHO), fuel and technology combinations are classified as clean if they achieve either the annual Average Air Quality guideline level (AQG) of 5 $\mu g/m^3$ or the Interim Target- 1 level (IT1) of 35 $\mu g/m^3$ for PM 2.5; or the 24-hour average air quality guideline level (AQG) of 4 mg/m^3 or the Interim Target-1 level (IT-1) of 7 mg/m^3) for CO.

In Nepal, the clean cooking technologies of tier 3 and above i.e. with thermal efficiency of 30% is considered clean. Renewable Energy Test Stations (RETS) is responsible for the tracking and measuring different parameters of various cookstoves. The efficiency of various tiers of cookstoves is outlined in Table 2.3.

Table 2.3: Tiers of cook stove

Parameter	Units	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
High power thermal efficiency	%	<0.15	≥0.15	≥0.25	≥0.35	≥0.45
Low power-specific consumption	MJ/min/L	>0.05	≤0.05	≤0.039	≤0.028	≤0.017
High power CO	g/MJ_d	>16	≤16	≤11	≤9	≤8
Low power CO	g/min/L	>0.2	≥0.2	≥0.13	≥0.1	≥0.09
High power PM	M_g/ MJ_d	>979	≤979	≤386	≤168	≤41
Low power PM	g/min	>8	≥8	≥4	≥2	≥1
Indoor emission CO	g/min	>0.97	≤0.97	≤0.62	≤0.49	≤0.42
Indoor emission PM	M_g/min	>40	≤40	≤17	≤8	≤2
Safety	Johnsons	<45	≥45	≥75	≥88	≥95

(RETS, 2014)

Furthermore, WECS has developed the hierarchy of different cookstoves and fuels used in Nepal based on their thermal efficiency as shown in Figure 2.5.

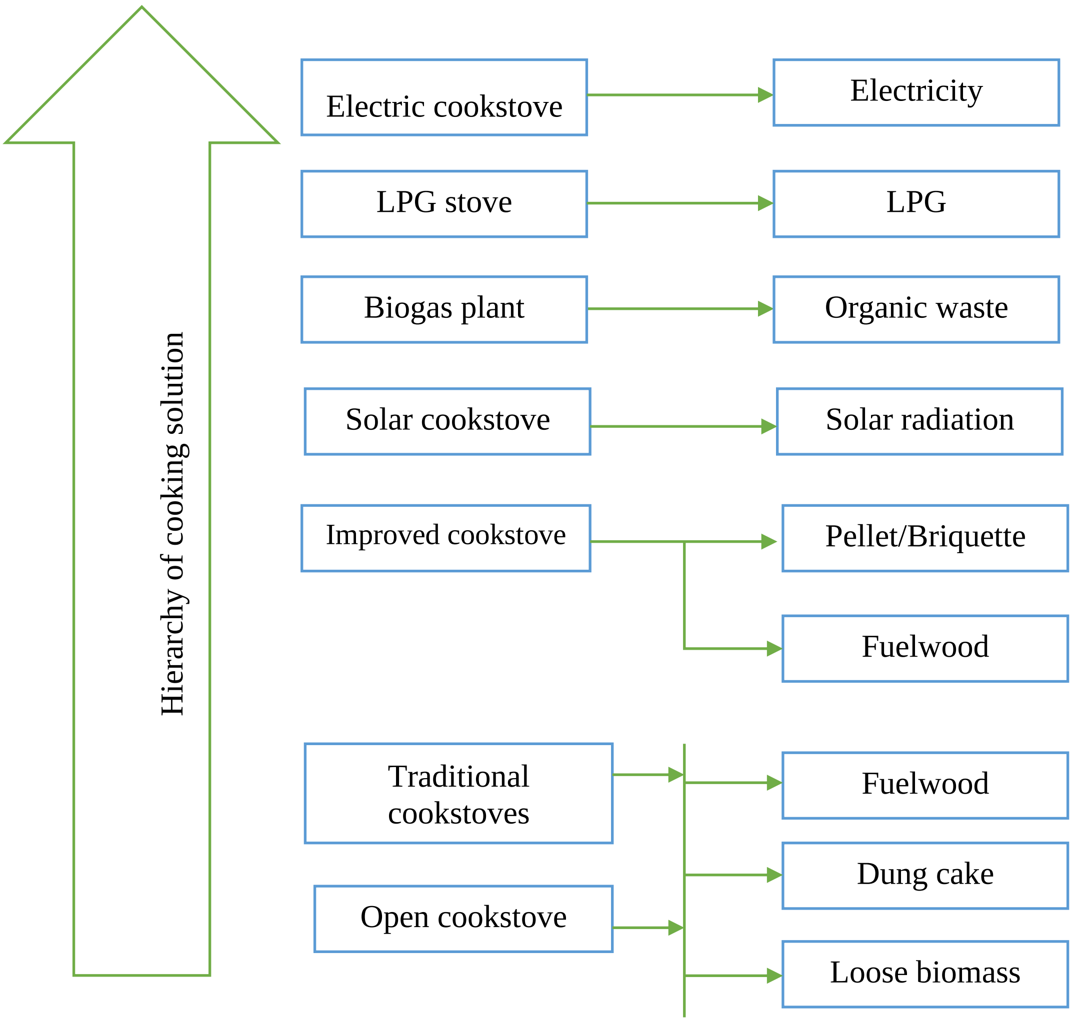


Figure 2.5: Hierarchy of cooking solutions

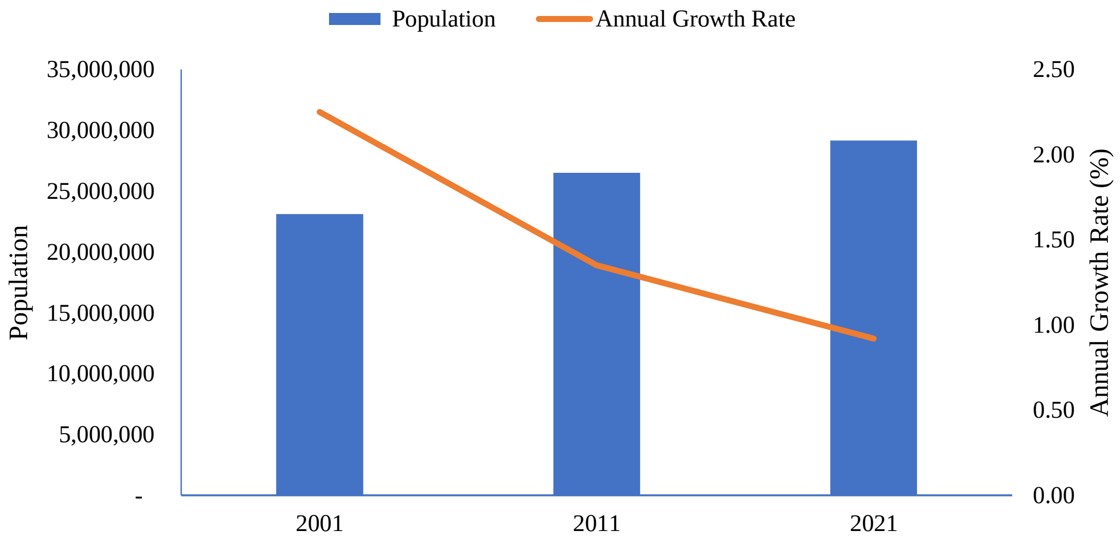
2.4 Macroeconomic status

Macroeconomic conditions play a crucial role in energy forecasting. Macroeconomic indicators such as Gross Domestic Product (GDP) growth, inflation, and population growth, among others, can significantly influence energy demand patterns over time. For instance, higher GDP growth rates are often associated with higher energy demand as businesses and households increase their consumption of energy-intensive goods and services and vice versa.

2.4.1 Population

Population growth plays a crucial role in predicting future energy requirements. It can greatly influence energy demand and resource availability within a specific area. With a larger population, the energy demand typically rises, potentially leading to the need for new energy infrastructure and production facilities. Furthermore, the increase in population can also lead to higher demands for transportation, encompassing both passenger and freight vehicles.

According to the Central Bureau of Statistics (CBS) 2021 report, Nepal is experiencing a consistent rise in its population, with an annual growth rate of 0.92%. As of 2021, the total population has surpassed 29 million. The urban population is expanding at an even faster pace of 1.44%, and it currently makes up 66% of the total population. The overall population and growth rate in Nepal are shown in Figure 2.6.



(CBS, 2022)

Figure 2.6: Population and growth rate of Nepal

Similarly, Biratnagar Metropolitan City's population is 2,43,927 and the total number of households is 56,919. The annual population growth rate of Morang District is 1.66% (CBS, 2022).

2.4.2 Gross domestic product

The Gross Domestic Product (GDP) of Nepal at constant 2011 price in the year 2022/23 was NPR. 2,576 billion with an increase of 2.15% in the current fiscal year, while in the previous year the growth in the GDP was 5.26%. The share of the transportation and storage in the overall GDP of the Nepal in FY 2022/23 was around 5.40% with a growth rate of 1.14% (CBS, 2022). The historical pattern for the change in GDP in Nepal is shown in Table 2.4.

Table 2.4: GDP of Nepal

Year	Overall		Accommodation and food service activities	
	In million (NPR.)	Growth (%)	In million (NPR.)	Growth (%)
2012/13	1,553,502	3.07%	27,851	6.92
2013/14	1,642,711	5.74%	28,269	1.50
2014/15	1,700,405	3.51%	29,799	5.41
2015/16	1,700,448	0.00%	27,420	-7.98
2016/17	1,846,506	8.59%	31,092	13.39
2017/18	1,982,653	7.37%	34,887	12.21
2018/19	2,109,263	6.39%	38,348	9.92
2019/20	2,058,149	-2.42%	24,245	-36.78
2020/21	2,150,497	4.49%	26,847	10.73
2021/22	2,263,570	5.26%	30,231	12.61
2022/23	2,312,383	2.16%	35,843	18.56

(CBS, 2022)

2.5 Energy system models: A review

Energy system models are mathematical models developed to represent various energy-related problems. These models can guide decision-making on power capacity expansion by illustrating different strategies to meet future demands and environmental targets. Typically, energy modelling tools can be categorized into three groups based on the approach used for the energy model.

2.5.1 Top-Down energy model

Top-down energy modeling is a methodology used to estimate the energy consumption and greenhouse gas emissions of a region, country, or the world as a whole. This approach starts by looking at aggregate data, such as gross domestic product and population, and then estimating energy use and emissions based on this data. The models used in top-down energy modeling can be simple or complex and may incorporate a range of assumptions and data sources. Despite some limitations, top-down energy modeling is useful for providing a high-level understanding of energy consumption and emissions trends and identifying areas for policy intervention.

2.5.2 Bottom-Up energy model

Bottom-up energy modeling is an approach that involves analyzing the energy consumption of individual buildings, processes, or equipment, and then aggregating the results to estimate energy use and greenhouse gas emissions at the regional or national level. This method starts with detailed data on energy use and emissions at the individual level and uses this information to build up a comprehensive picture of energy consumption and emissions across a region or country. Bottom-up energy modeling can provide a more detailed understanding of energy use and emissions trends and is useful for identifying specific areas where energy efficiency improvements can be made. However, it can be resource-intensive and may not capture all of the complexities of the energy system.

2.5.3 Hybrid energy model

A hybrid energy model is a methodology that combines elements of both top-down and bottom-up energy modeling. This approach uses both aggregate data and detailed information on individual buildings, processes, or equipment to estimate energy consumption and greenhouse gas emissions. Hybrid energy modeling aims to overcome some of the limitations of top-down and bottom-up modeling by providing a more comprehensive and accurate picture of the energy system. By combining the strengths of both approaches, hybrid energy modeling can provide insights into energy consumption and emissions trends at different levels of detail and can be useful for identifying opportunities for energy efficiency improvements and policy intervention. Examples of hybrid models include The Integrated MARKAL-EFOM System (TIMES) and the Long-range Energy Alternatives Planning System (LEAP).

2.6 Policy stock taking

2.6.1 Nationally Determined Contribution

In 2020, the Government of Nepal (GoN) upgraded its Nationally Determined Contribution (NDC) and submitted it to the United Nation Framework Convention on Climate Change (UNFCCC). The second NDC specifically targets five key sectors: (i) Energy Generation, (ii) Transportation, (iii) Residential Cooking and Biogas, (iv) Agriculture, Forest, and Other Land Uses, and (v) Waste Management. Under Residential Cooking and Biogas sectors, the NDC sets out the following quantifiable activity targets.

- By 2025, 500,000 improved cooking stoves, primarily in rural areas, and an additional 200,000 household biogas plants and 500 large-scale biogas plants (institutional/industrial/municipal/community) would be installed.
- By 2030, ensure that electric stoves are used as the primary mode of cooking in 25 % of households.

2.6.2 NDC Implementation Plan

Nepal has developed an implementation plan reiterating the target mentioned in the NDC and further distributing each target in a comprehensive set of activities along with their financing needs and costs. Nepal's NDC Implementation Plan outlines the country's ambitious climate goals and the financing needs associated with achieving them. The NDC implementation plan estimates that USD 33.05 billion is needed between 2021 to 2030 to implement the country's NDC commitments. To realize the conditional financing needs for the NDC implementation plan, Nepal prioritizes the grant based international public finance. The UNFCC climate change funds including GCF, GEF, AF, LDCF, SCCF and well as emission trading schemes will be the priority source of financing. Similarly, financing from other international development partners, multilateral development banks and philanthropic funds would be utilized to fulfil the NDC commitments.

2.6.3 National Adaptation Plan

The Government of Nepal has prepared the National Adaptation Plan (NAP) to accelerate its adaption priority for climate resilience society. The NAP sets out sixty-four priority programs in the nine thematic sectors in line with the National Climate Change Policy (2019). These sectors include agriculture and food security, forests, biodiversity and watershed conservation, water resources and energy, rural and urban settlements, industry, transport and physical infrastructure, tourism, natural and cultural heritage, health, drinking water, and sanitation, disaster risk reduction and management, GESI, livelihoods and governance.

Under the thematic sector of water resources and energy, NAP has set out a priority program titled "Promoting Energy Mix System for Industrial Sustainability and Climate Resilient Livelihoods" to identify, assess and develop diverse energy sources for energy resilience and increase energy mix in the national energy system by 2030. Similarly, under the same thematic sector, NAP has set out two more priority programs for promoting climate resilient renewable energy and development of clean technologies.

2.6.4 Long-term Strategy for Net-Zero Emissions

A long-term Strategy for Net Zero Emissions has been prepared with the ambitious target of achieving net zero carbon emissions by 2045. It further projects the emissions in different scenarios and develops the emission reduction pathways for achieving net zero emissions. The various strategic actions in the residential sector include

- Electrification in all end-use services in urban areas
- Promotion of clean cooking technologies with high efficiency and low emissions in rural areas
- Electrification in cooking, space heating, water heating, and lighting in rural areas
- Promotion of efficient technologies in all end-use services.

Based on these strategic actions, the residential sector has the potential to reduce the emission by 53% in 2030 and 100% in 2050 with additional measures as compared to the reference scenario. Similarly, total electrification in all commercial sectors has the potential to achieve 100% emission reduction by 2030 (Ministry of Forests and Environment, 2021).

2.6.5 Sustainable Development Goals-7

The Government of Nepal has developed a roadmap to achieve the Sustainable Development Goal (SDG) targets by 2030. SDG 7 specifically emphasizes promoting and ensuring access to clean and modern energy while enhancing overall energy efficiency across the country. The targets under SDG 7 by 2030 include: (i) achieving universal access to affordable, reliable, and modern energy services, (ii) significantly increasing the share of renewable energy in the global energy mix, and (iii) doubling the global rate of improvement in energy efficiency. The specific targets of the SDG 7 are

- Increase the access to electricity from 74% in 2015 to 90.7% in 2025 and 99% in 2030
- Decrease the share of households using solid fuels as the primary source of cooking from 74.7% in 2015 to 45% in 2025 and 30% in 2030
- Increase the share of households dependent on LPG from 18% in 2015 to 32% in 2025 and 39 in 2030
- Increase the share of renewable energy in final energy consumption from 11.9% in 2015 to 37.3% in 2025 and 50% in 2030

- Increase the energy-efficient appliances in the residential and commercial sectors from 10% in 2015 to 40% and 60% in 2025 and 2030 respectively

2.6.6 16th Five-Year Periodic Plan

The plan has a vision to achieve the SDGs and to promote a green economy through adaptation and mitigation of impacts of greenhouse gases on the environment, which are the present needs. The plan has set the strategy and working policy to utilize the locally available resources to promote renewable energy in Nepal. The major energy-related targets of the plan are as follows:

- Install 1,000,000 electric stoves and 645,000 improved cooking stoves by the end of Fiscal Year 2085/86 to promote sustainable energy use and improve air quality
- Produce 28,500 MW of electricity over the next 12 years, enhancing the capacity and reliability of Nepal's electricity supply through reservoir-based and non-reservoir-based hydropower projects with both domestic and international investments

The 16th periodic plan has also targeted installing an additional 500,000 household biogas plants and 645,000 improved stoves and gasifiers (thermal electric technology). It has aimed to increase the production of Bio-briquette pellets at the rate of at least 20,000 MT per year and substitute 40,000 MT of LPG through the installation of 500 high-capacity biogas plants.

CHAPTER THREE: METHODOLOGY

The review of literature has been done on the basis of relevant studies made in national and international level. The process of determining sample size has been done using Krejci and Morgan's formula. Required questionnaires to fulfill our objectives has been prepared and primary data was collected through field survey. The base year energy demand has been calculated and energy demand projection has been done. Finally, comparison of energy demand with different cities of Nepal has been done. The methodology followed for the accomplishment of study is shown in Figure 3.1.

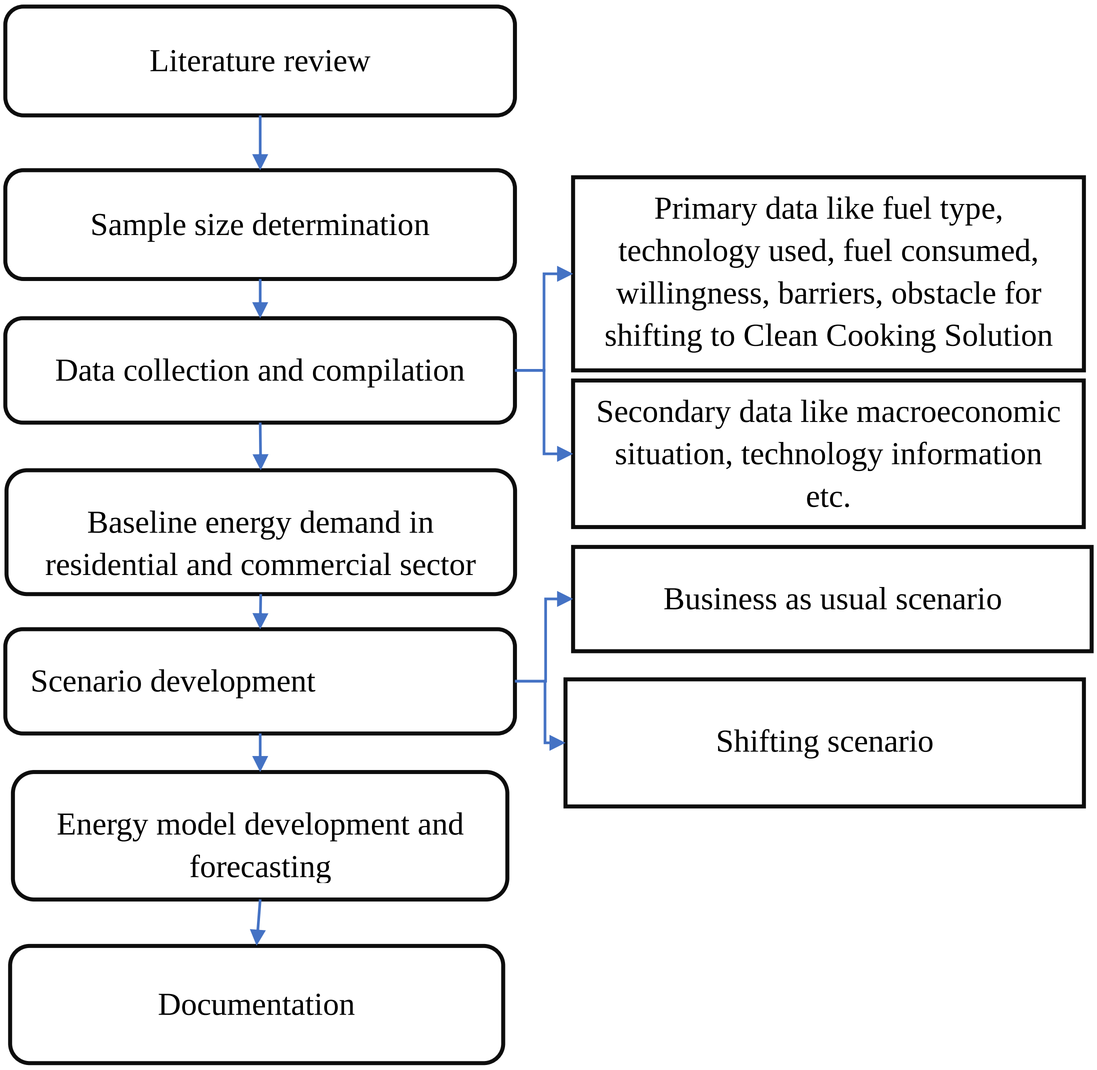


Figure 3.1: Methodological flowchart

3.1 Literature review

The literature review has been conducted to study the status of energy used for cooking. Similarly, the statistics and characteristics related to different cooking technologies and fuels has been done with the help of different modeling tools and techniques. In addition, different historical data published by the WECS, CBS, National Planning Commission etc. have been thoroughly examined. Similarly, the target set by the government in relation to promotion of clean cooking technologies and fuels like second Nationally Determined Contribution

(NDC), Long Term Strategy for Net Zero Emissions, Sustainable Development Goals have been thoroughly reviewed. Further different reports and journals published by government and non-government organizations has been reviewed during the study.

3.2 Sample size determination

Sampling is the method used to identify the number of samples and sample unit from a population using statistical method such that it possesses the characteristics of the population. Sampling has been done to identify the sample size and sample units in transportation sector. For proportionally determination of sample size, it was designed with 95% level of confidence with 5% marginal error and 5% non-response rate for the manufacturing industries. The sample size was calculated using Krejci and Morgan formula (Morgan K., 1970)

$$n = \frac{\chi^2 \times p \times q \times N}{e^2\,(N-1) + \chi^2 \times p \times q} \qquad \text{....(3.1)}$$

Where,

χ^2=χ square for specific confidence level (95%) = 3.841
p = Probability of success = 0.5
q= 1-p = probability of unsuccessful= 0.5
e = Margin of error
N = Population size
n = Required sample size
n_r: Total non-response rate = 5%,
Hence, total sample size = n+5% of n_r

3.2.1 Residential sector

Each household was considered a sample unit in the residential sector, with various wards serving as sampling locations. Households from diverse economic status, religious beliefs, and ethnic backgrounds were included based on CBS classification. Data collection also considered varying educational levels, house occupancy statuses, primary income sources, building types, and roof types. The number of households sampled was determined based on the preliminary findings of the 2021 census.

3.2.2 Commercial sector

The population size of the commercial sector is determined from the "National Economic Census" published by CBS in 2018. Within the commercial sub-sector, entities are further categorized according to the National Standard Industrial Classification (NSIC). This includes various types of establishments such as hotels and restaurants, hostels and hospitals, institutional canteens, party palaces, and banquet halls, among others, each categorized by their levels of energy consumption. Information regarding both the buildings and the institutions themselves were also evaluated.

3.3 Data collection and compilation

3.3.1 Primary data

The questionnaire-based survey has been employed for collection of primary data. A questionnaire incorporating various socioeconomic information, fuel consumption statistic, cooking pattern, barriers and hinderance for clean cooking prepared in coordination with the client. The interview with the respective representatives of households and commercial entities were conducted in Biratnagar to collect the data and information related to clean cooking technologies.

3.3.2 Secondary data

The process of gathering secondary data involves obtaining information from sources other than the primary users. This means that the data is pre-existing and has already been analyzed by someone else. For this study, secondary data has been taken from various sources, such as economic survey reports, energy survey reports, statistical documents, among others.

3.4 Determination of baseline energy demand

The energy consumption for cooking in the residential and commercial sectors was determined using a bottom-up approach. In this method, energy data were gathered from surveys and then aggregated to determine the specific energy consumption. Accordingly, the total energy consumption for different fuels used in the residential and commercial sectors were calculated. This approach allowed for a field-based energy consumption assessment within the residential and commercial sector.

$$\text{Annual energy consumption of vehicles, } E_x = \text{Quantity of fuel per month} \times \text{calorific value} \times \text{number of operating days} \quad \text{... (3.2)}$$

$$\text{Specific energy consumption} = \frac{1}{n}\sum(E_x) \quad \text{... (3.3)}$$

where x denotes different samples

$$\text{Total energy consumption of vehicles types} = \sum \text{Specific energy consumption} \times \text{no. of vehicles} \quad \text{... (3.4)}$$

Additionally, emissions for different fuels and technologies were also estimated during the study using their activity level and the emission factor. The emssions from different fuels has been estimated as folows:

$$Em_{i,j} = \Sigma_j Fc_j \times EF_{i,j} \quad \text{.... (3.5)}$$

where,

j = Type of fuel

$Em_{i,j}$ = Emission of pollutant i from fuel type j

Fc_j = Consumption of fuel type j (kg/yr)

$EF_{i,j}$ = Emission factor specific to pollutant i from fuel type j

(Shrestha, et al., 2013)

3.5 Financial assessment of cookstoves

The life cycle cost each type of cookstoves has been calculated using the data obtained from survey. The life cycle cost (LCC) is a comprehensive measure that captures all costs associated with the purchase, operation, maintenance, and disposal of a cookstove over its entire lifespan. It is an essential metric for comparing the economic feasibility of different cooking technologies. The LCC has been calculated using the formula.

$$LCC = C_i + \sum_{t=1}^{n} \frac{C_0(t) + C_m(t) + C_f(t)}{(1+r)^t} + \frac{C_d}{(1+r)^n} \quad \text{…. (3.6)}$$

Where,

C_i: Initial cost (purchase and installation) of the cookstove
$C_0(t)$: Annual operational cost at year t
$C_m(t)$: Annual maintenance cost at year t
$C_f(t)$: Annual fuel cost at year t
C_d : Disposal cost at the end of the lifespan
n: Lifespan of the cookstove (in years)
r: Discount rate (to account for the time value of money)

The emission factor of each type of GHGs and local pollutants have been taken to calculate the emissions from each type of fuel in each year using LEAP. In this way, the results have been calculated and comparative analysis has been done with different cities of Nepal.

3.6 Development of scenarios

During the study, two scenarios namely, Business as usual scenario and shifting scenario was developed while considering the historical trend along with government plans and policies. The business as usual scenario considered the historical pattern of energy use for cookin while the shifting scenarios considered the historical trend along with government target and policies to penetrate electric cooking . In shifting scenario, it was considered that 25% of households would be using electricity as primary source of fuel by 2030 and 100% households will be using electricity as primary fuel by 2050 under the shifting scenario. The energy demand has been sub-categorized and calculated on basis of fuel. GHG and various other pollutant emissions has been predicted for each scenario with an interval of 5 years till the year 2050

3.6.1 Energy model development and forecasting

3.6.1.1 Service demand projection

The service demand projection relies on economic and demographic parameters as the driving factors. The growth in the residential sector is directly influenced by population growth while that in the commercial sector is influenced by the gross value added, making these parameters critical for energy projection. By considering these factors, the study aims to create a realistic outlook for energy use, enabling better-informed decision-making to achieve long-term energy sustainability and environmental objectives.

The future energy and demand in the residential and commercial sector were estimated based on the service demand projection methodology. In case of the residential sector, the population elasticity was only considered while in case of the commercial sector the Gross Value Added (GVA) was only considered. The service demand has been calculated using the formula

$$Service\ demand\ of\ nth\ year\ in\ commercial\ sector = Service\ demand\ of\ base\ year \times \left(\frac{GVA\ of\ nth\ year}{GVA\ of\ base\ year}\right)^{\alpha_1} \quad \ldots(3.7)$$

$$Service\ demand\ of\ nth\ year\ in\ residential\ sector = Service\ demand\ of\ base\ year \times \left(\frac{Population\ of\ nth\ year}{Population\ of\ base\ year}\right)^{\alpha_2} \quad \ldots(3.8)$$

Where,

α_1 is elasticity for GVA

α_2 is elasticity for population

3.6.2 Energy model development

The energy model was developed based on the service demand projection approach. The useful energy analyzed from the baseline survey, along with efficiency, emission factor, and calorific value, were utilized to develop the energy model. To determine the energy consumption of different fuels at a five-year interval, energy intensity, i.e., specific energy consumption, was used. The methodology adopted for calculating the energy demand for cooking is shown in Figure 3.2.

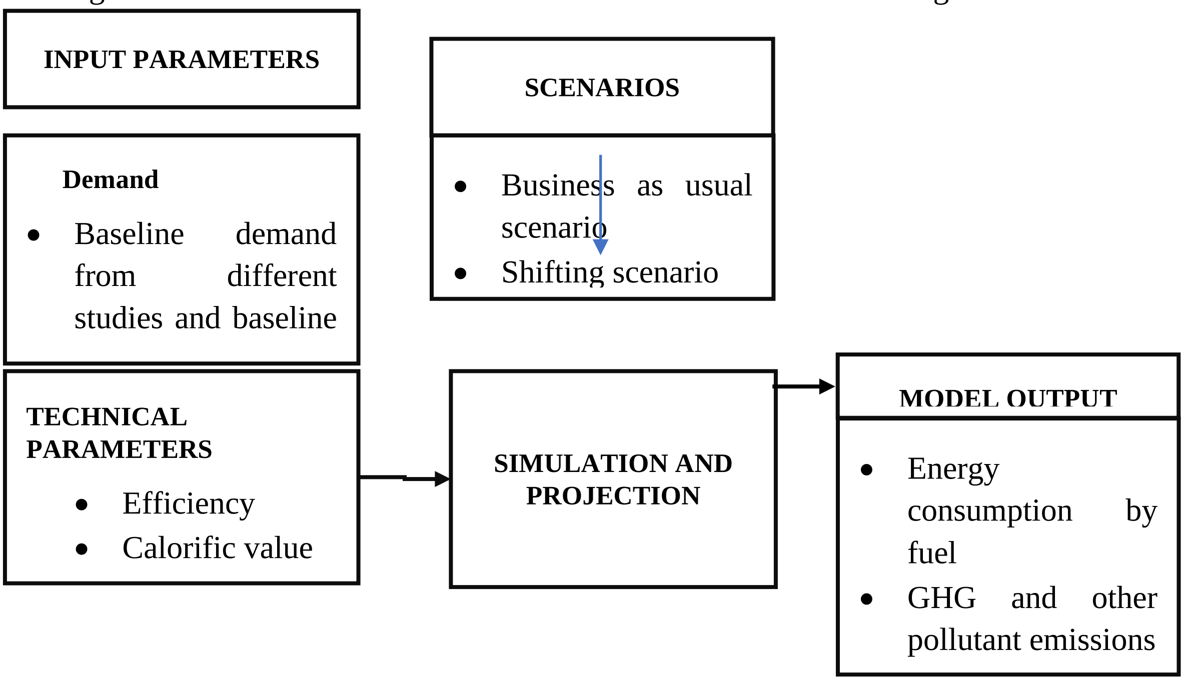


Figure 3.2: Modelling framework

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Project location

The project was carried out within Biratnagar Metropolitan City, located in the Morang District. This study focused on the residential and commercial sectors. Biratnagar Metropolitan City has a population of 243,927 and comprises 56,919 households. Additionally, there are 1,731 food and accommodation entities categorized according to the National Standard for Industrial Categorization (NSIC).

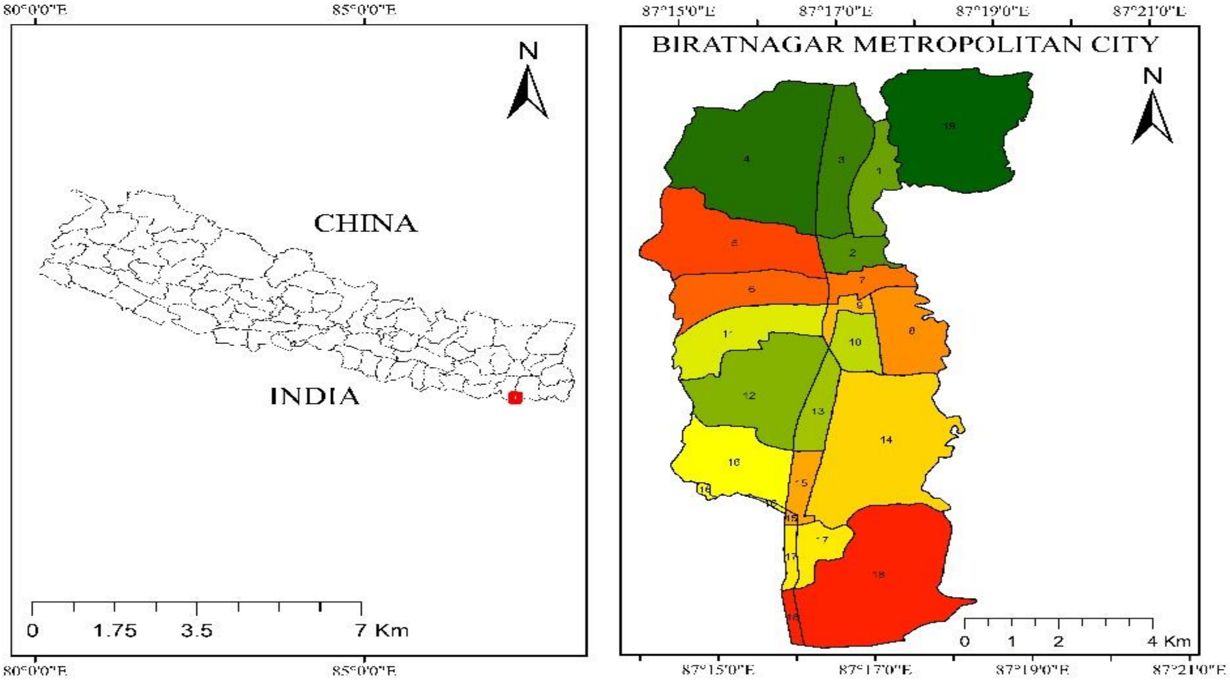


Figure 4.1: Survey location

The sample size has been divided among the 19 wards of Biratnagar Metropolitan City to get an inclusive and comprehensive status of cooking in both residential and commercial sectors.

4.2 Residential sector

4.2.1 Socioeconomic status

The survey was proportionated to each of the nineteen wards of Biratnagar Metropolitan City. Among the surveyed households, males were the primary household heads in 67.5% of cases, while females comprised the remaining 32.5%. The average household size within the sample was 4.66 persons (further details by ward are available in Annex 1). In terms of ethnicity, 39.7% of households identified within the *'Madhesi'*, followed by *'Janjati'* (23.5%), *'Pahadi Bahun'* (21.1%), *'Chhetri'* (8.3%), *'Muslim'* (6.9%), and *'Dalit'* (0.5%).

Table 4.1:Socioeconomic information of surveyed household

S.N.	Particulars	Quantity
1.	Total surveyed households	403
2.	Male headed households	275

S.N.	Particulars	Quantity
3.	Female headed households	133
4.	Average family size	4.66 person
5.	Average monthly family income	NPR. 26,823
6.	Distribution by ethnicity	*'Madhesi'*: 39.7%; *'Janjati'*: 23.5%, *'Pahadi Bahun'*: 21.1%, *'Chhetri'*: 8.3%, *'Muslim'*: 6.9%, and *'Dalit'* 0.5%

Further, the type of kitchen in different households was also identified during the survey. The survey found that most households in Biratnagar have indoor kitchens, with 70.59% lacking an exhaust system and 27.70% with exhaust. Also, a small minority, 1.70%, still rely on outdoor kitchens.

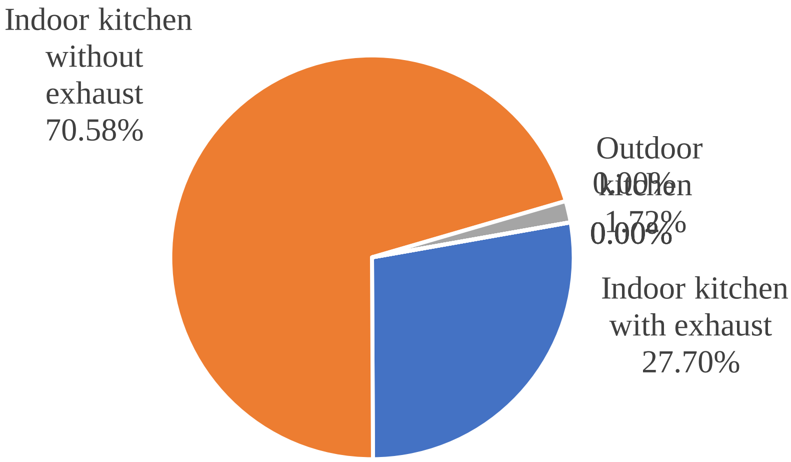


Figure 4.2: Type of kitchen

The fuse ratings provided by the Nepal Electricity Authority (NEA) were examined to further assess the feasibility of adopting electric cooking. These ratings include 6A, 16A, and 32A. Among the surveyed households, 19.36% were equipped with a 6A fuse, 79.9% with a 16 A fuse, and 0.74% with a 32 A fuse.

Table 4.2: Fuse rating in surveyed household

Fuse rating (A)	Total no. Households
6	19.36% (79 households)
16	79.9% (326 households)
32	0.74% (3 households)

4.2.2 Clean cooking technologies and fuels

A survey conducted in the residential sector of Biratnagar revealed a near-universal adoption of LPG stoves for cooking, with 99.75% of households utilizing this technology. Additionally, 12.99% of households use rice cookers, while 12.75% use biomass cookstoves.

Furthermore, with increasing access and awareness of electric cookstoves, 99.07% of households use electric cookstoves, mainly induction stoves. During the survey, it was also evident that electric technologies such as coil heaters, mud heaters, and kerosene stoves have been phased out, as none of the respondents reported using these technologies. The details of the different cookstoves used in Biratnagar are shown in Figure 4.3.

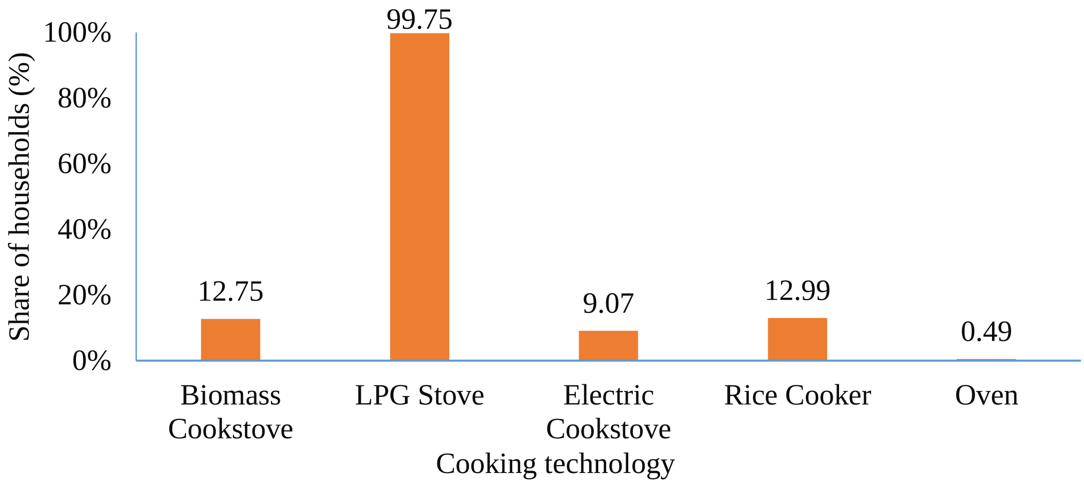


Figure 4.3: Cooking technologies in residential sector

Similarly, while most cooking technologies use a dedicated fuel, some, like biomass cookstoves, may use more than one fuel. More than one technology can also use more than one fuel, like rice cookers and electric cookstoves. The survey revealed that 99.75% of households use LPG gas as fuel, while 20.34% of households use electricity, and 12.01% use fuelwood. Similarly, 0.74% of households uses dung cake.

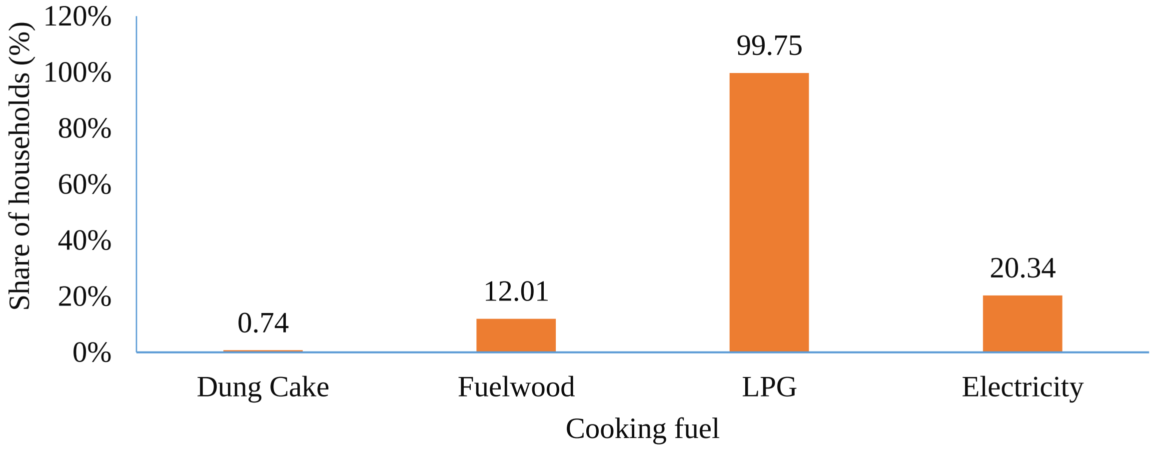


Figure 4.4: Cooking fuels in residential sector

4.2.3 Technologies and fuel stacking

Stove stacking refers to the use of multiple cookstoves within the household for same or different purposes. From the survey, it is observed that about 69.86% of households use only one type of cookstove while 25.73% of households uses two types of cookstoves, whereas 4.41% use more than two types of stoves for cooking. In most cases with two or more technologies, the rice cooker is predominating second technology as 11.27% of households use a combination of LPG and rice cooker for cooking.

Table 4.3: Stacking of cooking techniques in Biratnagar

Cookstove Type	Percentage (%)
LPG Stove	69.61
LPG Stove + Rice Cooker	8.82
LPG Stove + Rice Cooker + Oven	0.25
LPG Stove + Electric Cookstove	7.11
LPG Stove + Electric Cookstove + Oven	0.25
LPG Stove + Electric Cookstove + Rice Cooker	1.23
Biomass Cookstove	0.25
Biomass Cookstove + LPG Stove	9.80
Biomass Cookstove + LPG Stove + Rice Cooker	2.20
Biomass Cookstove + LPG Stove + Electric Cookstove + Rice Cooker	0.49

Similarly, in regards to the fuels used in Biratnagar, it was observed that, the type of fuel used varies from household to household and depends on the cooking technology employed in the households. In Biratnagar, 69.61% of the households use only LPG for cooking while 0.25% use only fuelwood for cooking. Similarly, 27.46% use two types of fuels while 2.70% use more than two types of fuels. The details of the fuel stacking are shown in Table 4.4.

Table 4.4: Stacking of cooking fuels in Biratnagar

Fuel Stacking	Percentage (%)
LPG	69.61
LPG + Electricity	17.65
Dung Cake + LPG	0.74
Fuelwood	0.25
Fuelwood + LPG	9.07
Fuelwood + LPG + Electricity	2.70

4.2.4 Energy consumption for cooking

According to the survey conducted during this study, the total energy consumption for cooking in residential sector in Biratnagar is found to be 515.28 TJ in 2024. The survey revealed that the predominant source of energy consumption was LPG, accounting for 414.00 TJ, followed by fuelwood at 61.33 TJ. Comparatively, electricity and dung cake constituted only 32.95 TJ and 6.99 TJ respectively. The overall energy consumption in the residential sector by fuel types is shown in Figure 4.5.

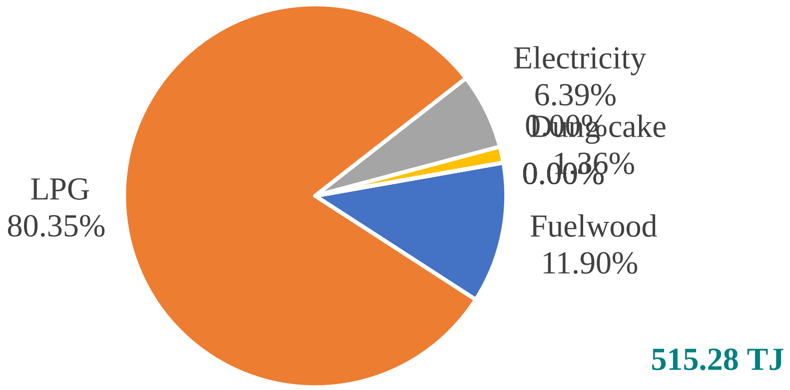


Figure 4.5: Final energy consumption in residential sector

Additionally, while the final energy is total energy produced due to combustion of fuel, it is necessary to access the energy delivered to the pot as well also known as useful energy. Overall, the useful energy for cooking in residential sector of Biratnagar is estimated to be 241.87 TJ in 2024. The survey revealed that the predominant source of useful energy was due to LPG, accounting for 198.72 TJ, followed by electricity at 29.66 TJ. Similarly, biomass and dung cake constituted 12.44 TJ and 1.05 TJ of the total energy consumption, respectively. The overall useful energy consumption in the residential sector by fuel types is shown in Figure 4.6.

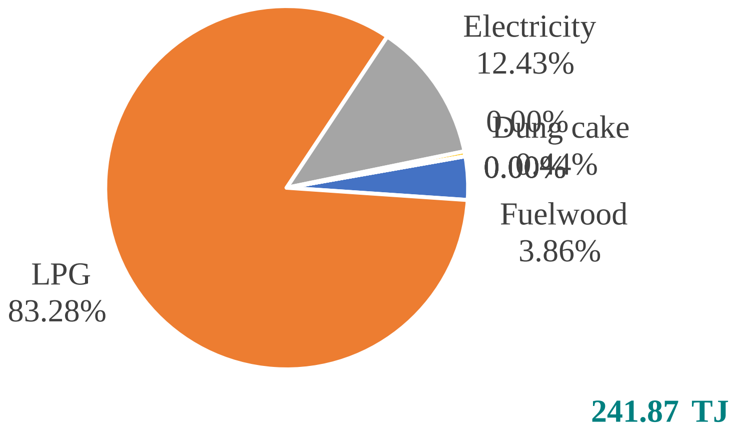


Figure 4.6: Useful energy consumption in residential sector

4.2.5 Emissions from residential cooking

The burning of different fuels in the kitchen results in the emissions of different Greenhouse Gases (GHG) emission. Based on the energy use in Biratnagar, LPG is the largest contributor of GHG emission at 26.82 thousand tonnes of CO_{2eq} followed by fuelwood and dung cake. The GHG emitted by the residential cooking sector of Biratnagar is shown in Table 4.5.

Table 4.5: GHG emissions from residential sector of Biratnagar

(In metric tonnes)

Fuel	CO_2	CH_4	N_2O	CO_{2eq}
LPG	26,820,292	1,260	810	26,822,362
Fuelwood	5,566,340	29,297	220	5,595,856
Dung cake	496,864	1,734	169	498,767
Total	32,883,496	32,291	1,198	32,916,985

4.2.6 Cost of cooking technology

The average life cycle cost of cooking technologies mainly used in the residential sector of Biratnagar is shown in Table 4.6. There are two components of cost involved with the cooking technology, technology cost and fuel cost. Obtaining information about the cost of cooking technologies used in the residential sector is firstly, allows policymakers and researchers to assess the affordability and accessibility of different cooking options for households, especially in low-income communities. By comparing the costs, it becomes possible to determine the financial benefits and potential savings associated with adopting cleaner cooking technologies, thereby motivating households to make environmentally friendly choices.

Table 4.6: Life cycle cost of cooking technologies in residential sector

Particulars	LPG stove	Electric stove	Biomass stove
Capital cost (NPR)	6,200	4,000	1,200
Annual maintenance cost (NPR)	620	400	120
Lifetime (Years)	5	4	2
Annual useful energy consumption (GJ/HH)	4.25	4.25	4.25
Annual final energy consumption (GJ/HH)	8.85	4.72	28.32
Annual consumption of fuel (kg, kWh, kg)	192.38	1,311.05	1,716.28
Unit price of fuel (NPR)	134.51	9.50	15.00
Annual cost of fuel (NPR)	25,876.71	12,454.94	25,744.19
Operating cost over life (NPR)	95,742.80	38,212.54	44,471.73
LCC (NPR)	101,942.80	42,212.54	45,671.73
Annual LCC (NPR)	26,892.25	13,316.83	26,315.61
Monthly LCC (NPR)	2,241.02	1,109.74	2,192.97

4.2.7 Users' perception

The households were interviewed regarding cooking convenience, cooking time efficiency, indoor pollution, health problems, and fuel cost efficiency of their current cooking technologies. Based on the information collected, it was analyzed that most of the respondent viewed their current cooking technologies as convenient technology that offers efficiency interims of both cooking time and fuel cost. The details of the user's perception based on the gender of the respondent of their cooking technologies are shown in Figure 4.7.

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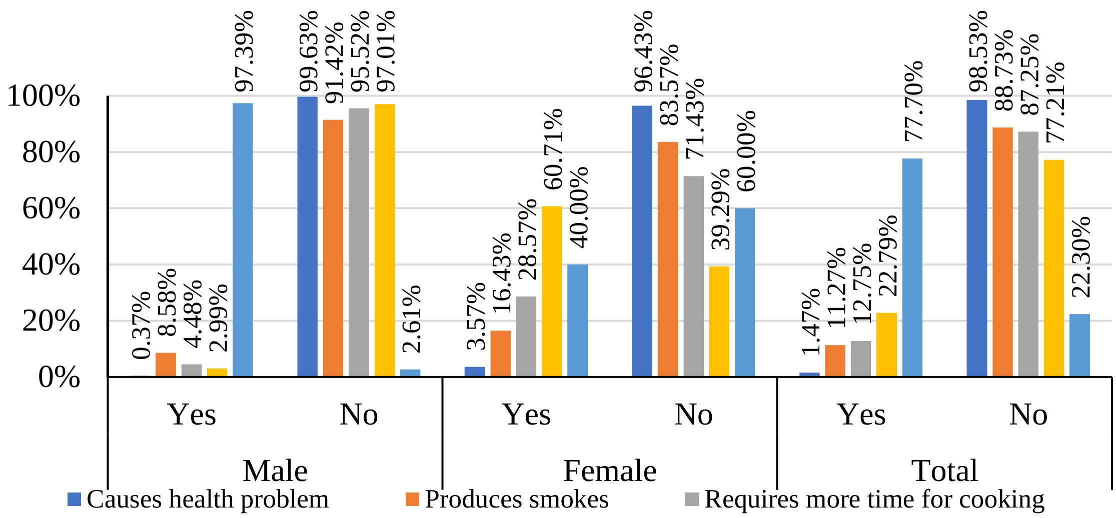

Figure 4.7: Consumers' perception towards current technology in Biratnagar

4.2.8 Willingness to use clean technology

During the survey, respondents showed notable interest in adopting new technologies. Among surveyed households, 49.00% expressed their interest in transitioning to electric cookstoves, while 0.25% indicated a willingness to switch to LPG cookstoves. A majority of those open to electric cookstoves currently use LPG stoves, whereas those considering LPG stoves predominantly use biomass cookstoves. Additionally, 50.75% of households expressed no inclination to switch from their current cookstoves.

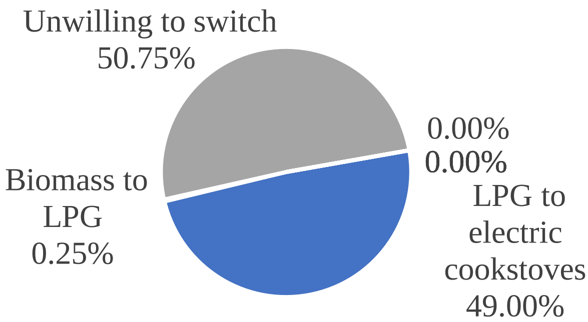

Figure 4.8: Consumer's willingness towards shifting technology

Similarly, the priority of the respondents regarding their opinion to switch to clean cooking technologies were further analyzed as shown in Figure 4.9. Their opinions were marked based on priority. The 11.03% of the respondents marked high priority for convenience in newer technology, while 40.03% of the respondents gave higher priority marking for using current expensive technology. Various factors, such as technological advancements, economic considerations, health concerns, and socio-cultural influences, impact the willingness of households to adopt improved technology. About 46.32% of newer technology was clean and healthy and was listed as a high priority. When conducting the survey, participants willing to switch were asked about their motivations for transitioning to the current technology.

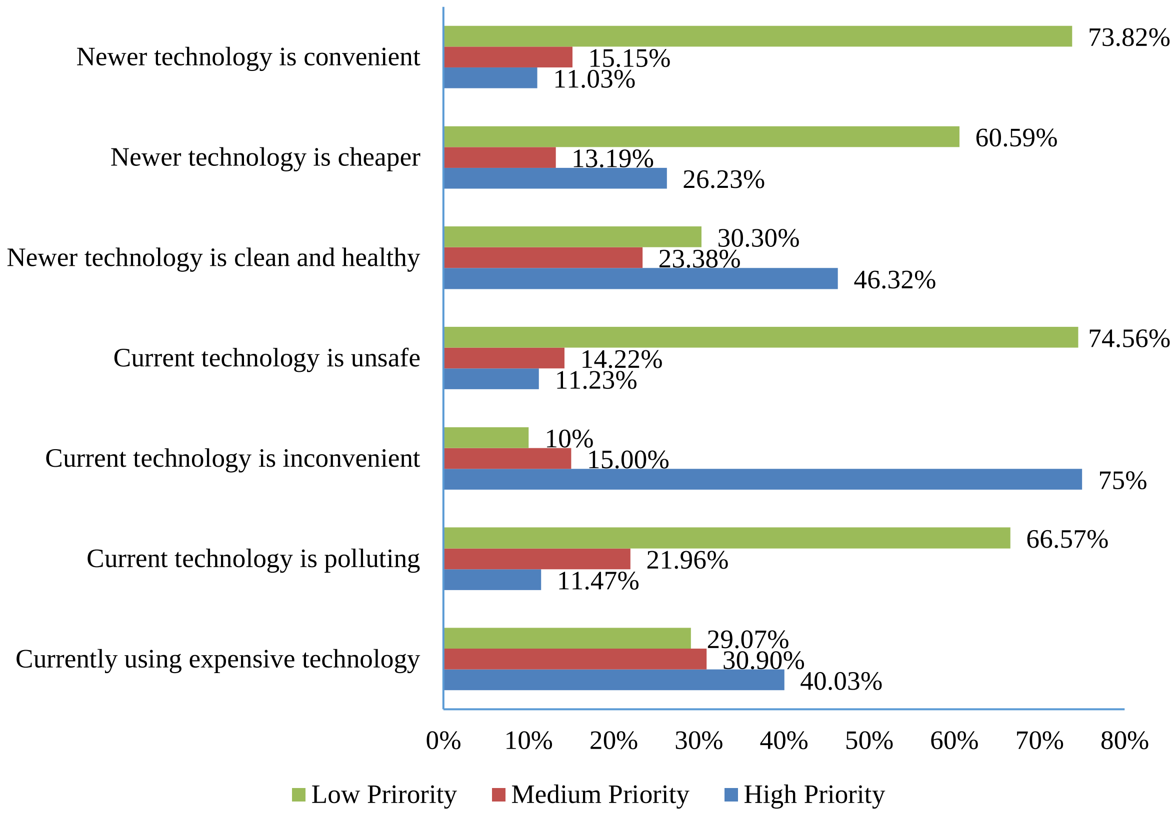

Figure 4.9: Reasons for shifting of residential area of Biratnagar

4.2.9 Barrier identification

The survey showed that not every respondent has been willing to switch to clean cooking technologies. Hence, these respondents were further queried regarding the barriers and obstacles towards clean cooking technologies. The major barriers identified based on their response include

- Unreliable infrastructures: Concerns about the reliability of new clean cooking technologies have been able to deter residents from transitioning from traditional methods. If the new technologies have been perceived as unstable or prone to malfunction, residents may have preferred to stick with familiar options.
- Initial cost of new technology has been high: When switching to new technologies, the households have had to bear upfront costs, fuel costs, and other operating costs associated with the cooking technologies. These costs, when added up together, might have reduced the affordability of the cooking technique.
- Unreliable newer technologies: Concerns about the reliability of new clean cooking technologies have been able to deter residents from transitioning from traditional methods. If the new technologies have been perceived as unstable or prone to malfunction, residents may have preferred to stick with familiar options.
- Lack of knowledge (use and maintain): If individuals have not been aware of the availability and benefits of clean cooking technologies, they may not have considered them as viable options. Lack of information can lead to a lack of

awareness about the negative environmental and health impacts of traditional cooking methods, as well as the advantages offered by cleaner alternatives.

- Lack of awareness about the negative impacts of traditional cooking: Residents may not have been sufficiently informed about the availability and benefits of clean cooking technologies. Without awareness, they have been less likely to seek out and adopt these technologies.

The distribution of respondents in terms of priority of Biratnagar Metropolitan City: The barriers have been classified as high, medium, and low priority.

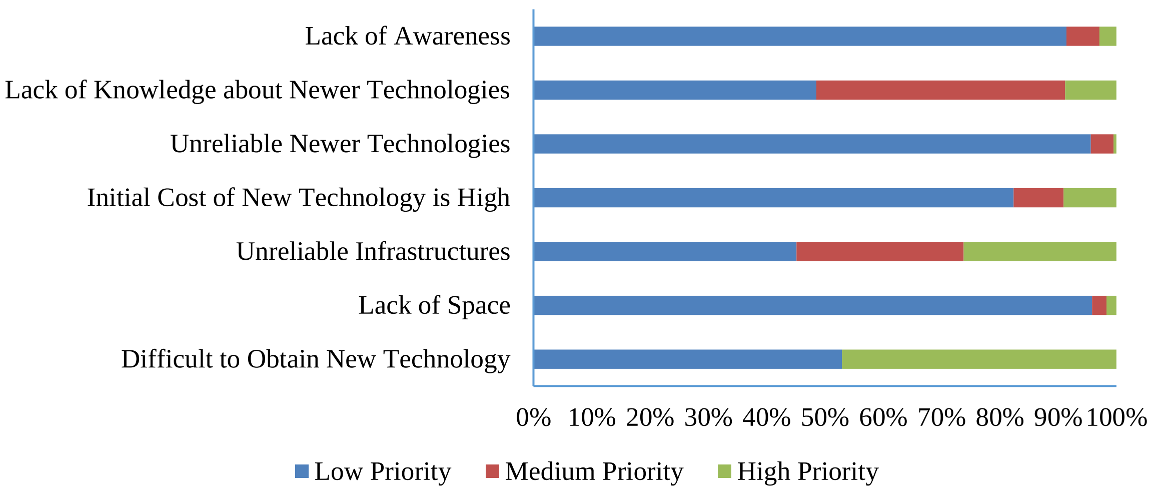

Figure 4.10: Barriers for shifting in residential areas of Biratnagar

The survey analyzed the respondents' preferences regarding potential incentives to prioritize shifting to electric cooking. The respondents were asked to rank their priorities for shifting to clean cookstoves. Most prioritized reducing the purchase cost of electric cookstoves, followed by subsidizing the utensils for induction stoves. The details of the users' priorities are shown in Table 4.7.

Table 4.7: Perception of users on current and newer technologies

Incentives	Priority		
	1st	2nd	3rd
Reduced purchase cost	49%	-	-
Subsidy on appropriate utensils used on induction stoves	23%	31%	-
Loan programmes	-	9%	20%
Provide professional installation for free	4%	6%	6%
Reduction in NEA tariff	10%	6%	2%
Availability of stable electricity	3%	22%	11%
Easy access to utensils for induction stove	1%	4%	18%
Easy process for shifting to 16 A and above electric meters	8%	7%	6%
Improvement in technology	1%	4%	8%
Cooking training on induction stoves	0%	12%	28%

4.2.10 Reasons for shifting

Various factors, such as technological advancements, economic considerations, health concerns, and socio-cultural influences, impact the willingness of households to adopt improved technology. When conducting the survey, participants willing to switch were asked about their motivations for transitioning to the current technology. The reasons for shifting as per the respondents of Biratnagar Metropolitan City are shown in Figure 4.11. According to the survey, most respondents, i.e., 30% of the respondents, wanted to switch due to the better technologies available in the market. Further, 20.63% of the respondents were interested in switching due to the lower cost of new technologies. Further, 13.44% of the respondents were willing to switch due to the chances of health hazards with current technologies.

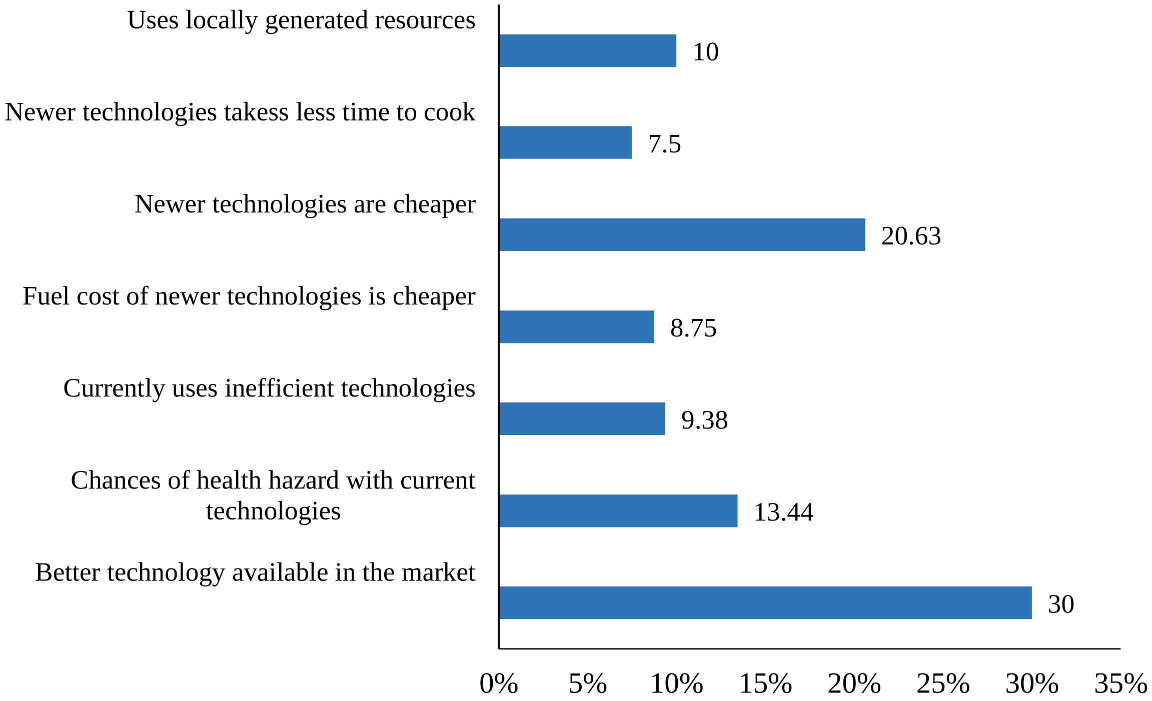

Figure 4.11: Reasons for shifting of residential area of Biratnagar

4.3 Commercial sectors

4.3.1 Clean cooking technologies and fuels

A survey conducted in the commercial sector of Biratnagar revealed a universal adoption of LPG stoves for cooking, with 100% of entities utilizing this technology. Additionally, rice cooker, electric cookstoves and oven have been found 39.32%, 15.38% and 6.84% respectively. Similarly, 2.28% of the entities uses biomass cookstoves while 0.57% uses furnace. During the survey, it was also evident that electric technologies such as coil heaters, mud heaters, and kerosene stoves have been phased out, as none of the respondents reported using these technologies. The detail of different cookstoves used in Biratnagar is shown in Figure 4.12.

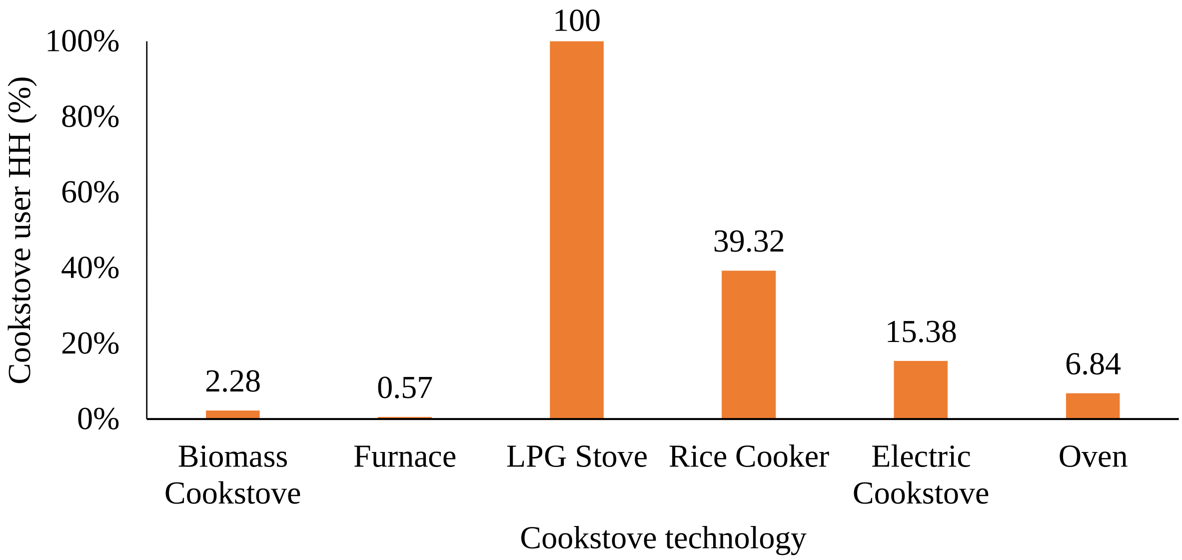

Figure 4.12: Cooking technologies used in commercial sector

Similarly, while most cooking technologies use a dedicated fuel, some, like biomass cookstoves, may use more than one fuel. More than one technology can also use more than one fuel, like rice cookers and electric cookstoves. The survey revealed that 100% of households use LPG gas as primary fuel, while 57.55% of households use electricity and 2.85% of households use fuelwood.

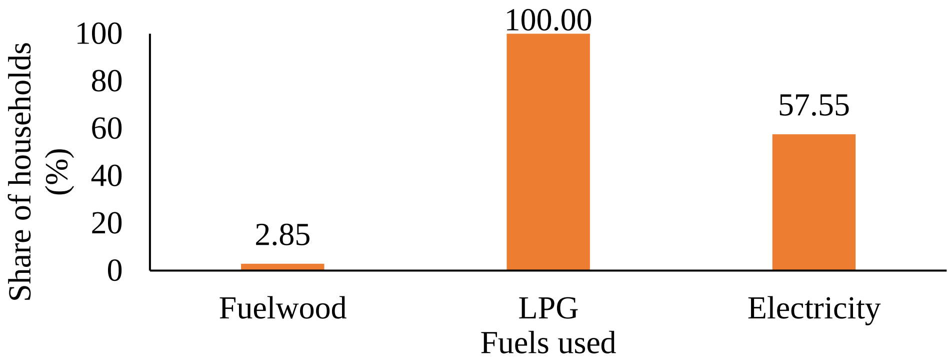

Figure 4.13: Cooking fuels used in commercial sector

4.3.2 Technologies and fuel stacking

Using multiple stoves provides cooking flexibility, and higher energy efficiency, and fulfils specialized cooking needs especially in the commercial entities with different food demands within certain time periods. From the survey, it was obtained that, 46.44% of the sectors use a single type of stove for cooking, 48.43% of the sectors utilize two cooking techniques and 5.13% utilize more than two. The various combinations of cooking techniques employed by the entities are shown in Table 4.8.

Table 4.8: Stacking of cooking technologies in Biratnagar

Cookstove Type	Percentage
LPG Stove	46.44%
LPG Stove + Electric Cookstove	12.82%

Cookstove Type	Percentage
LPG Stove + Oven	4.84%
LPG Stove + Oven + Furnace	0.57%
LPG Stove + Rice Cooker	29.63%
LPG Stove + Rice Cooker + Electric Cookstove	1.99%
LPG Stove + Rice Cooker + Oven	1.14%
LPG Stove + Rice Cooker + Oven + Electric Cookstove	0.28%
Biomass Cookstove + LPG Stove	1.14%
Biomass Cookstove + LPG Stove + Rice Cooker	0.85%
Biomass Cookstove + LPG Stove Rice Cooker + Electric Cookstove	0.28%

Similarly, in regards to the fuels used in Biratnagar, it was observed that, the type of fuel used varies abased on the type of commercial entities In Biratnagar 41.6% of the entities use only LPG for cooking. Similarly, 56.41% of entities use two types of fuels while 1.99% of the entities use more than two types of fuels. The details of the stacking are shown in Table 4.8.

Table 4.9: Stacking of cooking fuels in Biratnagar

Fuel Stacking	Percentage (%)
LPG	41.60
LPG + Electricity	55.56
Fuelwood + LPG	0.85
Fuelwood + LPG + Electricity	1.99

4.3.3 Energy consumption for cooking

According to the survey conducted during this study, the total energy consumption for cooking in commercial sector in Biratnagar is found to be 90.05 TJ in 2024. The survey revealed that the predominant source of energy consumption was LPG, accounting for 80.68 TJ, followed by electricity at 8.03 TJ. Comparatively, fuelwood constituted only 1.34 TJ. The overall energy consumption in the residential sector by fuel types is shown in Figure 4.14.

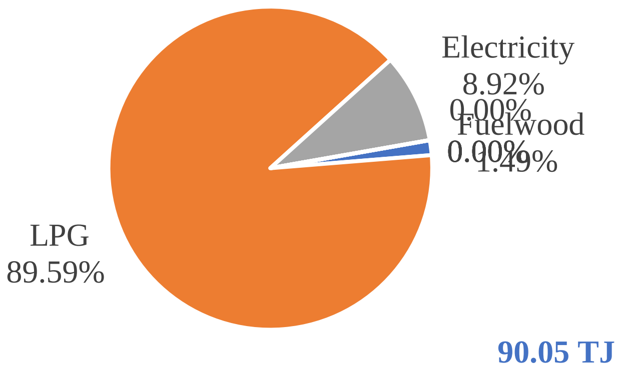

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Figure 4.14: Final energy consumption in commercial sector

Additionally, while the final energy is the total energy produced due to the combustion of fuel, it is necessary to access the energy delivered to the pot as well also known as useful energy. Overall, the useful energy for cooking in the commercial sector of Biratnagar has been estimated to be 46.35 TJ in 2024. The survey revealed that the predominant source of useful energy was due to LPG, accounting for 38.72 TJ, followed by electricity at 7.23 TJ. The overall useful energy consumption in the residential sector by fuel type is shown in Figure 4.15.

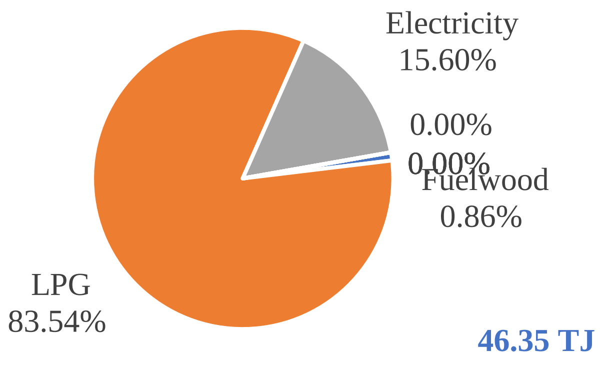

Figure 4.15: Useful energy consumption in commercial sector

4.3.4 Emissions from commercial cooking

Burning different fuels in the kitchen result in the emission of different greenhouse gases (GHG). Based on the energy use in Biratnagar, LPG is the largest contributor of GHG emissions at 5.18 thousand tonnes of CO_2eq, followed by fuelwood. The GHG emitted by the commercial cooking sector of Biratnagar is shown in Table 4.10.

Table 4.10: GHG emissions from commercial sector

Fuel	CO_2	CH_4	N_2O	CO_{2eq}
LPG	5,189	0.07	0.33	5,189
Fuelwood	227	0.0044	0.0044	227
Total	5,416	0.075	0.34	5,416

4.3.5 Cost of cooking technologies

Information regarding the cost involved with various cooking technologies in the commercial sector has been collected and analyzed. This data have been essential for understanding the financial conclusions of adopting different cooking options. Table 4.11 shows, the life cycle cost of various cooking technologies. The market price and monthly consumption data were taken as per data collected survey data and their life cycle cost were compared. The electric cookstoves were found to be efficient compared among other cooking technologies.

Table 4.11: Life cycle cost of various cookstoves used in commercial sector

Particulars	LPG stove	Electric stove	Biomass stove
Capital cost (NPR)	6,200	4,000	1,200
Annual maintenance cost (NPR)	620	400	120
Lifetime (Years)	5	4	2
Annual useful energy consumption (GJ/HH)	26.77	26.77	26.77
Annual final energy consumption (GJ/HH)	55.77	29.74	178.47
Annual consumption of fuel (kg, kWh, kg)	1,212.41	8,262.35	10,816.16
Unit price of fuel (NPR)	134.51	9.50	15.00

Particulars	LPG stove	Electric stove	Biomass stove
Annual cost of fuel (NPR)	163,077.61	78,492.28	162,242.42
Operating cost over life (NPR)	615,842.14	247,542.03	281,369.50
LCC (NPR)	622,042.14	251,542.03	282,569.50
Annual LCC (NPR)	164,093.15	79,354.17	162,813.85
Monthly LCC (NPR)	13,674.43	6,612.85	13,567.82

4.3.6 Users' perception

The households were interviewed regarding cooking convenience, cooking time efficiency, indoor pollution, health problems, and fuel cost efficiency of their current cooking technologies. Based on the information collected, it was analyzed that most respondents viewed their current cooking technologies as convenient technology that offer efficiency in terms of both cooking time and fuel cost. The details of the user's perception based on the gender of the respondent of their cooking technologies are shown in Figure 4.16.

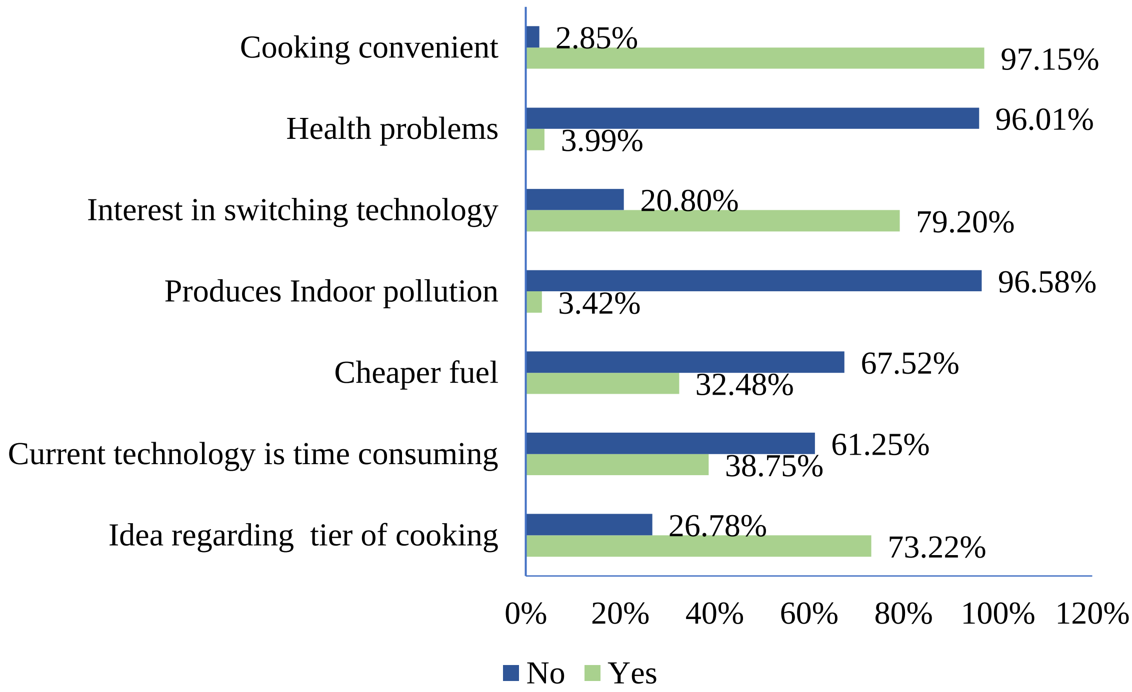

Figure 4.16: Consumers' perception towards current technology in Biratnagar

4.3.7 Willingness to use clean technology

During the survey, there was notable interest among respondents in adopting new technologies. Of the commercial entities surveyed, 79.00% of the entities expressed their interest to transition to electric cookstoves, while 0.20% of the entities indicated a willingness to switch to biogas. A majority of those open to electric cookstoves currently use LPG stoves, whereas those considering LPG stoves predominantly use biomass cookstoves. Additionally, 20.08% of the entities expressed no inclination to switch from their current cookstoves.

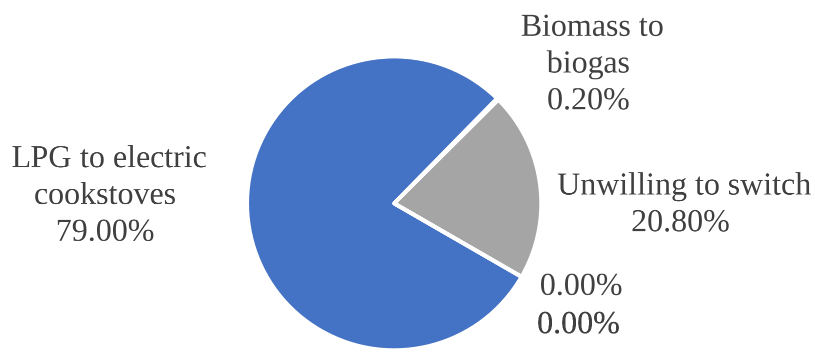

Figure 4.17: Consumer's willingness towards shifting technology

Based on surveyed commercial entities, 25.64% perceived their current technology as already good, 43.30% found it easy to use and maintain, 26.50% noted fast cooking, and 4.56% deemed it safe and reliable. In contrast, comments on new technology have revealed various concerns: 3.70% of users have noted electric cooking is not readily available, 29.34%, and so on. The detail of the users' perception is shown in Table 4.12.

Table 4.12: Perception of users on current and newer technologies

Current technology	Users' perception	New technology	Users' perception
Already good	25.64%	Not readily available	3.70%
		Too complex to use	29.34%
Easy use and maintain	43.30%	Unsafe	1.14%
		Expensive	21.65%
Fast cooking	26.50%	Unavailability of compatible cookware	1.14%
		Lack of information	27.35%
Safe and reliable	4.56%	Lack of skill and infrastructure	6.84%
		Lack of space	8.83%

4.3.8 Reasons for shifting

Table 4.13 shows users' incentives to shift towards clean cooking technologies according to their priorities. Users have prioritized reducing purchase costs the most, with 240 users as their top priority. Subsidies on appropriate utensils used in induction stoves have been priorities as an incentive by 65 users, with 9 placing it first and 56 placing it second. Loan programs have been given priority by 57 users, while professional installation for free has been prioritized by 67 users, and the reduction in NEA tariffs has been ranked by 111 users. Availability of stable electricity has been a concern for 180 users and so on. These priorities indicate a clear demand for cost-effective, accessible, and well-supported induction stove technology.

Table 4.13: Priorities of users in technologies

Incentives	Priorities						
	1st	2nd	3rd	4th	5th	6th	7th

Incentives	Priorities						
	1st	2nd	3rd	4th	5th	6th	7th
Reduced purchase cost	240	-	-	-	-	-	-
Subsidy on appropriate utensils used in induction stove	9	56	-	-	-	-	-
Loan programme	17	38	2	-	-	-	-
Provide professional installation for free	4	40	21	2	-	-	-
Reduction in the NEA tariff	16	38	42	14	1	-	-
Availability of stable electricity	6	62	64	36	11	1	-
Easy access for utensils for induction stove	9	2	6	12	9	1	-
Easy process for shifting to 16A and above electric meters	50	24	4	6	4	2	-
Improvement in technology	1	7	19	8	6	1	1
Cooking training on electric stoves	14	20	5	2	3	1	-

4.4 Energy demand forecasting

Two scenarios, Business as Usual and Shifting Scenario, have been considered to forecast the energy demand of Biratnagar's cooking sectors. Various assumptions were developed to determine the energy demand. Energy intensity, i.e., specific energy consumption, was used to determine the energy consumption of different fuels.

4.4.1 Business as usual scenario

The penetration of different fuels in terms of final energy and useful energy for both the residential and commercial sectors in Biratnagar, in 2024 is shown in Table 4.14. In the residential sector, dung cake has accounted for 1.36% of the final energy and 0.44% of the useful energy, indicating its inefficiency. Fuelwood has contributed 11.90% to the final energy and 3.86% to the useful energy, reflecting moderate efficiency. Electricity has made up 6.39% of the final energy but significantly more in useful energy at 12.43%, showcasing high efficiency. LPG has dominated the residential sector, constituting 80.34% of the final energy and 83.28% of the useful energy, suggesting both high usage and efficiency.

Similarly, in the commercial sector, fuelwood has had a penetration of 1.49% in final energy and 0.44% in useful energy, indicating low efficiency. Electricity has accounted for 8.92% of the final energy and 15.66% of the useful energy, showing higher efficiency. LPG has been the most prevalent fuel in the commercial sector, with 89.59% of the final energy and 83.90% of the useful energy, demonstrating its dominant role and efficiency in commercial cooking activities. It has been assumed that the trend of fuel penetration for both sectors remain the same in the upcoming years, with the distribution and efficiency of fuel usage observed in 2024 expected to continue without significant changes.

Table 4.14:Penetration of different fuels

S.N.	Fuel	Penetration of fuels in % (2024)	
		Final energy	Useful energy
Residential sector			
1.	Dung Cake	1.36%	0.44%
2.	Fuelwood	11.90%	3.86%
3.	Electricity	6.39%	12.43%
4.	LPG	80.34%	83.28%
Commercial sector			
1.	Fuelwood	1.49%	0.44%
2.	Electricity	8.92%	15.66%
3.	LPG	89.59%	83.90%

Based on the assumptions in this scenario, energy consumption for cooking in the residential sector of Biratnagar is projected to rise from 515.29 TJ in 2024 to 922.36 TJ by 2050. Similarly, in the commercial sector, the energy demand for cooking has been forecasted to increase from 90.05 TJ in 2024 to 249.72 TJ by 2050. The energy demand in the residential sector is projected to increases by 44.13% while that in commercial sector increases by 63.93%. The proportion of different cooking fuels in the final energy demand of residential sector is shown in Table 4.15.

Table 4.15: Projection of energy demand for residential sectors of in BAU scenario

Year	Energy consumption (TJ)				
	Biomass	LPG	Electricity	Dung cake	Total energy
2025	62.78	423.78	33.73	7.17	527.46
2030	70.55	476.24	37.91	8.05	592.76
2035	79.00	533.25	42.45	9.02	663.71
2040	88.37	596.53	47.49	10.09	742.48
2045	98.54	665.15	52.95	11.25	827.89
2050	109.79	741.06	58.99	12.53	922.37

Similarly, the energy demand of commercial sectors of Biratnagar is forecasted to become 249.72 TJ in 2050. The overall energy demand of commercial sectors of Biratnagar is shown in Table 4.16.

Table 4.16: Projection of energy demand for commercial sectors in BAU scenario

Year	Energy consumption (TJ)			
	Biomass	LPG	Electricity	Total energy
2025	1.37	83.89	8.35	93.62
2030	1.67	102.08	10.16	113.92
2035	2.03	124.21	12.37	138.62
2040	2.47	151.13	15.05	168.67
2045	3.01	183.90	18.31	205.23
2050	3.66	223.76	22.28	249.72

The total final energy demand from cooking in both the commercial and residential sectors in Biratnagar has been projected to reach 1172.09 TJ by 2050 as illustrated in Figure 4.18.

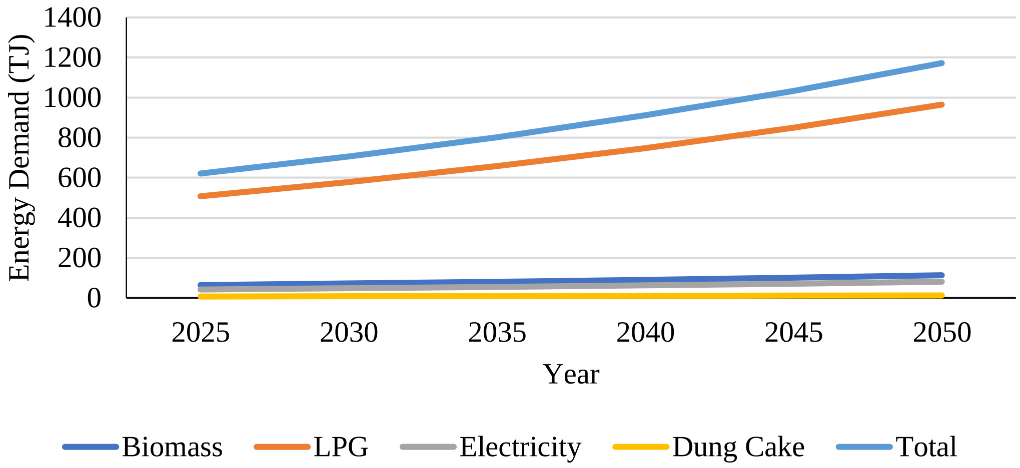

Figure 4.18: Projection of total final energy demand of Biratnagar

4.4.2 Shifting scenario

The shifting scenario has been shaped by altering the penetration levels of various fuels. The energy demand forecast under this scenario has been coordinated with Nepal's Long-term Strategy for Net Zero Emission Plan, which sets a target for complete reliance on electricity by 2045. Nepal's 2nd Nationally Determined Contribution aims to ensure that 25% of households use electricity as their primary fuel source. Consequently, the trends in the share of other fuels in the residential and commercial sectors have been adjusted accordingly. This adjustment has ensured that the penetration rates of different fuels have aligned with the assumption of electricity comprising 25% of the energy mix by 2030. The penetration of different fuels in the residential and commercial sectors has undergone significant changes. Over time, the share of non-electric fuels has gradually decreased, mirroring the anticipated shift towards exclusive reliance on electricity by 2050. This strategic adjustment has been pivotal in forecasting energy demand, ensuring that the evolving fuel usage trends align with Nepal's long-term sustainability objectives. Based on the above-mentioned assumption, the penetration of different fuels in the residential sectors of Biratnagar is shown in Table 4.17.

Table 4.17: Penetration of fuels in residential sectors of Biratnagar under shifting scenario

Year	Energy consumption (TJ)				
	Biomass	LPG	Electricity	Dung cake	Total energy
2025	40.41	422.56	38.53	4.61	506.12
2030	0	428.96	76.22	0	505.19
2035	0	390.81	133.08	0	523.89
2040	0	314.27	214.43	0	528.70
2045	0	187.95	325.75	0	513.70
2050	0	0	474.60	0	474.60

Similarly, the energy demand of commercial sectors of Biratnagar is forecasted 142.24 TJ in 2050. The overall energy demand of commercial sectors of Biratnagar is shown in Table 4.18.

Table 4.18: Projection of energy demand for commercial sectors of Biratnagar under shifting scenario

Year	Energy consumption (TJ)			
	Biomass	LPG	Electricity	Total Energy
2025	0.93	81.61	9.65	92.19
2030	0	79.58	22.45	102.03
2035	0	72.89	40.08	112.97
2040	0	59.64	64.27	123.91
2045	0	37.30	97.01	134.31
2050	0	0.00	142.24	142.24

Based on the assumptions outlined in this scenario, the forecast indicates that energy demand first increases and then decrease to 616.85 TJ by 2050. This condition would be met if all other cookstoves were completely replaced by electric cookstoves by 2050. This trend of energy consumption change is visually represented in Figure 4.19.

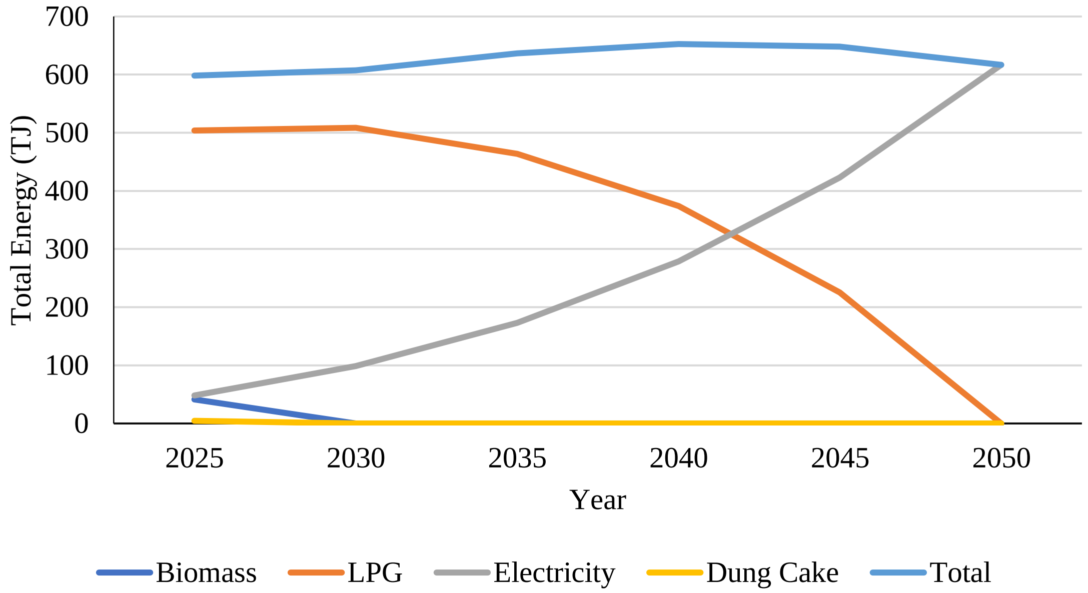

Figure 4.19: Projection of final energy consumption of Biratnagar under shifting scenario

Useful energy is the energy used for cooking. It considers the efficiency and losses associated with the technology. Hence, it can be used as a better tool for estimating energy requirements in the future. The overall useful energy in Biratnagar is expected to become 555.16 TJ. The trend of useful energy in Biratnagar is shown in Figure 4.20.

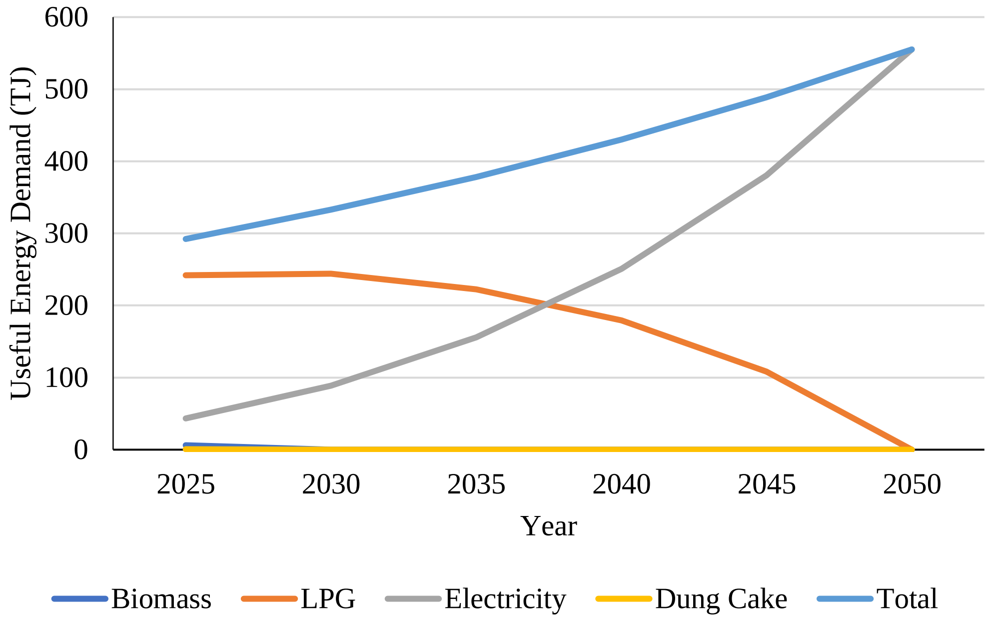

Figure 4.20: Useful energy projection for Biratnagar under shifting scenario

4.4.3 Projection of Greenhouse Gases

The emissions of Greenhouse Gases (GHG) for the final year has been calculated on the basis of predicted energy demand. The total GHG emissions for the year 2030 and 2050 are compared with each other.

Business as Usual Scenario

The GHG emission in the base year for the residential sector is estimated to be 37.861 $thMTCO_{2eq}$ at 100-year Global Warming Potential (GWP). Looking ahead, the sector's emissions are projected to experience a Compounded Annual Growth Rate (CAGR) of 2.3% until 2030. Following this period, the emissions are expected to continue increasing at a slightly lower rate of 2.1% until the year 2045. The overall GHG emission in the BAU scenario is shown in Table 4.19

Table 4.19: GHG emissions from residental sector

(000 $MTCO_{2eq}$)

GHG	2030	2050
Carbon dioxide (CO_2)	37.82	58.86
Methane (CH_4)	0.04	0.06
Nitrous Oxide (N_2O)	1.3×10^{-3}	2.2×10^{-3}
Total	37.861	58.92

The GHG emission in the base year for the commercial sector is estimated to be 6.76 $thMTCO_{2eq}$ at 100-year global warming potential (GWP). Looking ahead, the sector's emissions are projected to experience a compounded annual growth rate (CAGR) of 3.8% until 2030. Following this period, the emissions are expected to continue increasing at a same rate of 3.8% until the year 2045. The overall GHG emission in the BAU scenario is shown in Table 4.20.

Table 4.20: GHG emissions from commerical sector

(000 $MTCO_{2eq}$)

GHG	2030	2050
Carbon dioxide (CO_2)	6.76	14.82
Methane (CH_4)	10^{-3}	2×10^{-3}
Nitrous Oxide (N_2O)	2.1×10^{-4}	4.1×10^{-4}
Total	6.761	14.822

Shifting Scenario

The GHG emission in the base year for the residential sector is estimated to be 27.79 th$MTCO_{2eq}$ at 100-year global warming potential (GWP). Looking ahead, the sector's emissions are projected to experience a compounded annual growth rate (CAGR) of 2.3% until 2030. Following this period, the emissions are expected to continue increasing at a slightly decrease rate of 2.1% until the year 2045. The overall GHG emission in the shifting scenario is shown in Table 4.21.

Table 4.21: GHG emissions from residental sector

(000 $MTCO_{2eq}$)

GHG	2030	2050
Carbon dioxide (CO_2)	27.78	0
Methane (CH_4)	10^{-3}	0
Nitrous Oxide (N_2O)	1.3×10^{-3}	0
Total	27.79	0

The GHG emission in the base year for the commercial sector is estimated to be 27.79 th$MTCO_{2eq}$ at 100-year global warming potential (GWP). Looking ahead, the sector's emissions are projected to experience a compounded annual growth rate (CAGR) of 3.8% until 2030. Following this period, the emissions are expected to continue increasing at a same rate of 3.8% until the year 2045. The overall GHG emission in the shifting scenario is shown in Table 4.22.

Table 4.22 : Table GHG emissions from commerical sector

(000 $MTCO_{2eq}$)

GHG	2030	2050
Carbon dioxide (CO_2)	5.15	0
Methane (CH_4)	2.4×10^{-4}	0
Nitrous Oxide (N_2O)	10^{-4}	0
Total	5.15	0

CHAPTER FIVE: COMPARATIVE ANALYSIS

Comparing the specific energy consumption of different cities can provide valuable information regarding their energy efficiency and sustainability. By analyzing and comparing energy consumption patterns, it becomes possible to identify cities that are utilizing energy resources more efficiently and effectively. This information can highlight best practices, technologies, and policies that contribute to reduced energy consumption and environmental impact. Additionally, such comparisons can shed light on the factors influencing energy consumption variations, such as population density, climate conditions, urban planning, infrastructure, and cultural practices. Understanding these differences can aid policymakers, urban planners, and energy experts in formulating strategies to optimize energy usage, promote renewable energy sources, and develop more sustainable and resilient cities.

5.1 Comparison of total final energy of residential sector

The comparison between the specific energy consumption of the residential sector in terms of total final energy consumption is shown in Table 5.1, 3.06 GJ/Capita, is of Pokhara, while the lowest is of Biratnagar, i.e., 2.11 GJ/Capita. This is due to the high concentration of biomass-based fuel in this region. Furthermore, the total final energy of electricity is highest in Pokhara and lowest in Biratnagar. The energy demand of Kathmandu Valley is found to be 92.35% more than that of Biratnagar. Similarly, the energy demand of Butwal is found to be 7.02% more and that of Pokhara is found to be 67.50% more than the energy demand of Biratnagar. Using this information, the policymakers can develop an appropriate action plan to penetrate electricity use in these regions.

Table 5.1: Comparison of final energy consumption of residential sector

S.N.	Fuel type	Final energy consumption (TJ)			
		Biratnagar	Kathmandu Valley	Butwal	Pokhara
1.	LPG	414	4,096.29	310.2	902.76
2.	Biomass	61.34	2,151.47	184.5	422.65
3.	Biogas	0	1.57	0.803	15.05
4.	Dung cake	6.99	0	0	0
5.	Electricity	32.95	486.63	58.74	245.5
Total		515.28	6,735.96	554.24	1,585.96
Population		243,927	3,017,030	195,054	518,452
Specific energy consumption (GJ/capita)		2.11	2.23	2.84	3.06

5.2 Comparison of total useful energy of residential sector

Comparison between the specific energy consumption of the residential sector in terms of useful energy consumption is shown in Table 5.2. From the survey, it has been observed that the lowest specific energy consumption is in Kathmandu Valley of about 0.90 GJ/Capita, while the highest specific energy consumed, i.e., 1.40 GJ/Capita is of Pokhara.

This is due to the high concentration of electricity in this region, which is a highly efficient fuel. Using this information, the policymakers can develop an appropriate action plan to penetrate electricity use in these regions.

Table 5.2: Comparison of useful energy consumption of residential sector

S.N.	Fuel type	Useful energy consumption (TJ)			
		Biratnagar	Kathmandu Valley	Butwal	Pokhara
1.	LPG	198.72	1,966.21	148.9	433.32
2.	Biomass	12.44	322.72	27.68	63.39
3.	Biogas	0	0.58	0.3	5.57
4.	Dung cake	1.05	0	0	0
5.	Electricity	29.66	437.96	54.04	225.86
Total		241.87	2,727.47	230.92	728.14
Population		243,927	3,017,030	195,054	518,452
Specific energy consumption (GJ/capita)		0.99	0.90	1.18	1.40

5.3 Comparison of total final energy of commercial sector

Table 5.3 compares the commercial sector's specific energy consumption in terms of total final energy consumption. From the surveys conducted and previous data on clean cooking in major cities, it has been observed that the highest specific energy consumed, i.e., 107.74 GJ/entities, in Kathmandu Valley and the lowest is in Biratnagar, i.e., 52.02 GJ/entities. This is due to the high concentration of LPG in this region and lower dependence on electricity. This can potentially be attributed to reduced utilization of low-energy efficient fuels such as LPG, biomass-based fuels, coal, and biogas.

Table 5.3: Comparison of final energy consumption of commercial sector

S.N.	Fuel type	Final Energy Consumption (TJ)			
		Biratnagar	Kathmandu Valley	Butwal	Pokhara
1.	LPG	80.68	2,760.16	72.94	479.3
2.	Biomass	1.34	14.36	3.59	9.5
3.	Coal	0	380.38	0	0
4.	Biogas	0	0	0	0.017
5.	Electricity	8.03	39.43	5.3	31.84
Total		90.05	3,194.33	81.83	520.66
Population of entities		1,731	29,648	1,512	5,403
Specific energy consumption (GJ/Entities)		52.02	107.74	54.12	96.37

5.4 Comparison of total useful energy of commercial sector

Table 5.4. shows the comparison of specific energy consumption in terms of useful energy in the commercial sector. Kathmandu exhibits the highest specific energy consumption

50.45 TJ, while Butwal demonstrates the lowest, i.e., 26.73 TJ. This finding suggests that in regions with a significant reliance on LPG and biomass-based fuels, policymakers can formulate plans and policies to promote the adoption of energy-efficient alternatives. By targeting these areas with targeted initiatives, such as promoting the use of cleaner fuels, it has been possible to improve energy efficiency and reduce environmental impact in these regions.

Table 5.4: Comparison of useful energy consumption of commercial sector

S.N.	Fuel type	Useful Energy Consumption (TJ)			
		Biratnagar	Kathmandu Valley	Butwal	Pokhara
1.	LPG	38.72	1,324.88	35.01	230.06
2.	Biomass	0.4	2.15	0.54	1.43
3.	Coal	0	133.13	0	0
4.	Biogas	0	0	0	0.01
5.	Electricity	7.23	35.49	4.87	29.29
Total		46.35	1495.65	40.42	260.79
Population of entities		1,731	29,648	1,512	5,403
Specific energy consumption (GJ/Entities)		26.78	50.45	26.73	48.27

Various plans and policies can be implemented to inspire the people of Biratnagar to use efficient cooking technologies so that the specific energy consumption can be increased by a sufficient amount. Commercial entities completely using electric cookstoves can be provided subsidies on their income tax and loans on lower interest rates, and the electricity tariffs can be reduced for commercial entities to motivate them towards using cleaner cooking technologies. If efficient cooking technology is implemented in cooking technology, the energy consumption of cooking could be decreased sufficiently amount.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Following conclusions have been drawn from the study

Residential sector

- In residential sectors, 99.75% of households use LPG stoves along with other cooking technologies, while 12.99% use rice cookers, 12.75% use biomass cookstoves, and 9.07% use electric cookstoves. Based on fuel, 99.75% of households use LPG, 20.34% use electricity, and 12.75% use fuelwood as the source of fuel for cooking.
- Regarding stove stacking, 69.86% of households use single-type stoves, 25.73% use two-type cook stoves, and the remaining percentage of households use more than two-type cook stoves.
- The households using biomass cookstoves only are found to be 0.25% while 9.80% of households use biomass cookstoves with LPG.
- The total final energy consumption in Biratnagar is 515.28 TJ while the total useful energy consumption is 241.87 TJ. Further, the specific energy consumption per capita is 0.98 GJ/capita.
- The willingness to switch during the survey was estimated to be around 49.05% of the households in favour of switching to cleaner technologies.
- The total CO_2 emissions from LPG, fuelwood, and dung cake were found to be 26,820.29 tonnes, 5,566.33 tonnes, and 496.86 tonnes, respectively. Similarly, methane and nitrogen dioxide emissions from these sources were also found to be 1.26 tonnes, 29.28 tonnes, and 1.73 tonnes, respectively.
- The major barriers to shifting were identified as difficulty obtaining new technology due to the higher initial investment in switching to electric cookstoves. Most respondents considered unreliable electricity and infrastructures a major barrier to shifting towards clean technology.
- In the BAU scenario, the demand is expected to increase from 515.28 TJ in 2024 to 3,210.68 TJ in 2050. Further, in the shifting scenario, the final energy demand in the residential sector is expected to be 952.09 TJ, 1,666.30 TJ, and 1,652.07 TJ for 2035, 2045, and 2050, respectively.

Commercial sector

- In Biratnagar Metro City, 100% of commercial entities are using LPG for cooking along with other technologies while 15.38% of commercial entities only use electric cook stoves for cooking. Also, rice cookers, biomass cook stoves, furnaces, and oven were used by 39.32%, 2.28%, 0.57% and 6.84% respectively. In regards to cooking fuels, 100% of commercial entities use LPG while electricity and fuelwood are used by 57.55%, and 2.85% of commercial entities respectively.
- Among the commercial entities 46.44% use single stoves, 47.29% of entities use two-type stoves and 5.11% of entities use three or more type stoves. On the other

hand, 41.60% use one type of fuel while 55.56% use two types of fuel and the remaining percentage of commercial entities use more than two types of fuel for cooking. Since all of the commercial entities use LPG for cooking, it is the most dominant cooking fuel used followed by a combination of LPG and electricity, which covers 55.56% of the share.

- The total final energy consumption in the commercial sector of Biratnagar is 90.05 TJ while the total useful energy consumption is 46.15 TJ. Further, the specific energy consumption per capita is 26.66 GJ/capita.
- The total CO_2 emission from LPG, and biomass cookstoves were found to be 5189.57 tonnes, 227.21 tonnes respectively. Similarly, methane and nitrogen dioxide emissions were also found to be 0.075 tonnes and 0.25 tonnes respectively from the emissions of LPG, fuelwood and dung cake.
- Most of the respondents who were not willing to shift towards new technology had issues with the compatibility aspects of utensils with new cooking technologies along with huge investment to be done initially. Similarly, some of the respondents didn’t rely on the existing infrastructures for shifting towards clean technology.
- The energy demand is expected to increase to 138.62 TJ, 205.23 TJ, and 249.72 TJ for the years 2035, 2045, and 2050 respectively for the BAU scenario. In the shifting scenario, the final energy demand in the commercial sector is expected to be 122.64TJ, 144.74 TJ, and 142.24 TJ respectively.

6.2 Recommendations

Based on this study, the following recommendations are provided:

- Currently, the ratio of useful energy to final energy in the residential sector and commercial sector are around 0.46, which while represent tier 3 and above cooking technologies can further be improved with the penetration of electric cookstoves. Also penetration of electric cookstove can decrease the dependence on imported fuels while increasing the energy security as well.
- The share of households using electricity for different cooking technologies in residential sector is 20.34%, however most of them are using the rice cookers and only around 9.07% uses electric cookstoves i.e. induction and infrared cookstoves. While the increasing share of electricity in the energy mix for cooking is exciting, the current trend doesnot achieve the targets of Second NDC which states 25% of the household uses electricity as primary source for cooking. Hence mass penetration of electric cooking is needed to achieve targets of second NDC.
- Furthermore, widespread electric cooktop adoption necessitates infrastructure upgrades within residences. Existing 6-amp fuses are inadequate, and even 16-amp fuses restrict maximum uses of two induction stoves and infrared stoves. This poses a challenge for multi-family dwellings within a residential building and commercial settings, thus requiring higher fuse capacities.
- To make electric cooking technology more reliable, the electric infrastructures needs to be upgraded so that there would be no power interruptions during peak

operation time. Upgrading transformer and electricity distribution line is the most important step for making the electric infrastructure more reliable for cooking. Similarly, the size of wire and conductors inside the buildings must be replaced with higher one which ensures the reliability of electric cookstoves.

- The survey states 49.05% of households are willing to switch towards clean cooking technologies. Subsidies or loans can address the barrier of high initial cost for electric cooktops (replacing LPG). Thus, implementing a subsidy program or low-interest loan scheme targeting at least 50% of Biratnagar's households can incentivize a significant shift and achieve substantial emission reduction.
- Similarly, in the commercial sector, 79% of entities expressed their willingness to shift towards cleaner cooking technology, but the lack of repair and maintenance service for electric cookstoves has hindered them from switching to electric cooking. Conduction of government-led training sessions to empower users with skills for effective maintenance and enhancing longevity and efficiency of electric cooking technologies can be made to make electric cooking more reliable.
- The survey in residential sectors revealed that 9.07% of the respondents expressed the desire for a higher initial investment in electric cookstoves. Similarly, 240 of the respondents among the surveyed commercial entities want the price of electric cookstoves to be decreased. So, the price of electric cookstoves can be reduced by providing a subsidy on tax and custom duty to increase the number of primary users.
- From our survey, it was found that the people using biogas in Biratnagar is negligible. Providing access to biogas companies can be a better option for penetrating biogas as a cooking fuel in the city. This would also help in biodegradable and animal waste management.
- Although different policies are being made to implement electricity as a primary fuel for cooking, the availability of spare parts of electric cookstoves and skilled manpower for cookstoves repair/maintenance is difficult. So, easy availability of spare parts and repair centers of electric cookstoves must be done. The local government can provide training to people for maintenance of electric cookstoves and establish electric cookstoves repair centers.

6.3 Action Plans

Action plan can act as a framework for bringing regulation and uniformity to increase the status of clean cooking with increase in energy efficiency and reduction of greenhouse gas emissions. The following action plans are recommended to encourage residential and commercial entities for clean cooking technology:

S.N.	Strategic action	Targets	Responsible Organization	Estimated time frame
For Improved Cookstoves:				
1.	Replacing traditional cookstoves with	• Providing awareness and training programmes to targeted group about the	MoEWRI, AEPC, Federal and local	2026

S.N.	Strategic action	Targets	Responsible Organization	Estimated time frame
	improved cookstoves	health and environmental benefits of clean cookstoves • Providing subsidies on improved cookstoves for economically weak, marginalized and female headed households to replace traditional cookstoves.	government bodies	
2.	Providing improved cookstoves to households with lower fuse ratings	• Households with weak economic conditions and having lower rating of fuses can be provided with improved cookstoves on subsidy	AEPC, Province government and Local government	2026
For Biogas:				
1.	Construction of biogas plant and usage of biogas as cooking fuel	• Introduction of biogas companies in the places with low biogas users. • Providing subsidies to family having livestock on the construction of biogas plant • Installation of large size biogas plants to use biogas for commercial purposes	AEPC, Provincial and Local government bodies	2027
2.	Capacity building	• Provide training and certification for biogas repair and maintenance • Easy availability of spare parts and repair centers for components of biogas	WECS, AEPC, local government bodies	2027
For Electric Cooking:				
1.	Preparation of Electric Cooking Act	• Provisions that mandate regular monitoring and reporting of cooking status throughout the city and implementation of energy efficiency technologies • Outline the certification process for cookstoves repair technician,	MoEWRI, WECS and NPC	2026

S.N.	Strategic action	Targets	Responsible Organization	Estimated time frame
		cookstoves repair centres		
2.	Identification of large energy consumers in commercial sectors	• Monitor and track cooking energy consumption in different institutions and provide them recommendations for efficient cooking technologies	MoEWRI, WECS, NEA and Local Government	2025
3.	Capacity building	• Establishment of local industries for the production of electric cookstoves • Provide training on electric cookstoves repair • Easy availability of spare parts and repair centers for electric cookstoves • Community based cookstoves repair centers can be established in rural areas to make e-cooking reliable	MoF, WECS, AEPC and Local Government	2030
4.	Building codes for wiring to ensure safety and reliability of e-cooking	• Study for policies preparation to make building codes compulsory on newly constructed buildings • Formulate corresponding codes for each group while segregating the codes based on the physiographical region • Upgrading of wire size and conductor size to at least 4 mm2 to make e-cooking safe and reliable	MoEWRI, NEA and Local government	2026
5.	Upgrading of transformers and distribution system	• Upgrading the size of transformers and distribution lines to make electric infrastructures more reliable	MoF, MoEWRI and NEA	2030
6.	Financial incentives for electric cooking	• Provide financial incentives in forms of tax	MoF, AEPC, NEA and Local government	2028

S.N.	Strategic action	Targets	Responsible Organization	Estimated time frame
		benefits, subsidy, grants and soft loans to implement e-cooking • Distribution of at least 2000 electric cookstoves in each rural and urban municipality to marginalized and economically weak families through green climate fund programme of AEPC • Reduction in tariff rate of NEA on the basis of time period to influence people use electricity for cooking.		

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ANNEXES

Annex 1: Questionnaire for residential Sector

Water and Energy Commission Secretariat
Government of Nepal
Singhadurbar, Kathmandu
Present status and future plan of clean cooking technologies in major cities of Nepal

Residential Sector

Date: **Inspection No.**

1. Information of respondent & location

Name of respondent:	Contact no:
Age:…………… Ethnicity ============================	Gender ☐ Male ☐ Female ☐ Others
District: Morang	Metropolitan: Biratnagar
Ward number:	Name of the tole:

2. General Information of Household

Name of household head: …………………………	No. of family members : ……………
Educational status of household head	
☐ Illiterate ☐ Informal education ☐ Primary level	☐ Lower secondary ☐ Secondary level ☐ Higher education
House occupancy status ☐ Own ☐ Rent ☐ Institutional ☐ Other (specify) …………… Number of family residing within the house _………………	
Major sources of income ☐ Agriculture ☐ House rent/ Land lease ☐ Business ☐ Job/Service	☐ Pension ☐ Foreign employment/remittance ☐ Salary/Wages ☐ Other (specify) ……………
Average monthly family income NPR……………………………	
Distance from market ==============	Distance from main road/ highway =====================
Type of kitchen ☐ Indoor without exhaust ☐ Indoor with exhaust ☐ Outdoor	

3. Technology and fuels

3.1 Please select the technology and fuels used	
Technologies ☐ Traditional cookstove ☐ Open stove ☐ Improved cookstove ☐ Husk cookstove] ☐ LPG ☐ Briquette stove ☐ Biogas stove ☐ Furnace ☐ Induction	Fuels ☐ Fuel wood ☐ Agriculture residue ☐ Dung cake ☐ LPG ☐ Briquette/coal ☐ Biogas ☐ Diesel ☐ Wax ☐ Electricity

Coil heater Others	Solar Others
3.2 Size of stove (number of burners)	Quantity of stove : Number of burnersM
3.3. Cooking time	
When do you cook ?	Time AM…………. PM……….
Breakfast	
Lunch	
Snacks	
Dinner	

4. Energy consumption for cooking

4.1 Non- Electricity Energy consumed for cooking per month		
Equipment	Fuel	Quantity per month
Traditional cookstove	Fuelwood (in Bhari) Agricultural residue (in kg) Dung cake(in kg)	
Improved cookstove		
Husk cookstove	Husk (in kg)	
LPG stove	LPG (in cylinder)	
Briquette stove	Briquette (in kg)	
Biogas stove	Biogas	
Kerosene stove	Kerosene (In liter)	
Other ===========		

4.2 Peak operation time of electricity energy and equipment				
Equipment	Number	Peak operation time	Rating (Watt)	hrs./day
Coil heater				
Hot plate				
Induction cookstove				
Rice cooker				
Electric kettle				
Oven				
Infrared cooking				
Electric pressure cooker				
Grinder mixer				
Solar technologies				
Others specify				

5. Energy supply for cooking technologies

5.1 For fuelwood energy source			
Source of fuelwood	Forest	Own farm	Local market

Distance from source (km)			
Quantity of collection each time (Bhari)			
Time to collect the fuelwood (hr.)			
Frequency to collect/buy wood per month			
Cost to buy per bhari (NPR.)			

5.2 For agricultural residue energy source

Area of farm land …………………..
Quantity of agriculture residue produced …………………….

5.3 For animal dung energy source

Number of livestock ===================
Quantity of animal waste produced ………………..kg per day

Do you make guinthaa?	Yes ☐ No ☐
Quantity of guitha	……………quintal per year lSjG6n k|lt jif{

5.4 For biogas plant energy source

Installed year	…………………
Capacity of plant (m^3)	…………………
Operating condition	Working ☐ Not working ☐

5.5 For briquettes energy source

Source	Market	Domestic production
Quantity consumed per year (kg)		
Price (per kg)		

5.6 For electricity source

Source ;	National Grid
Fuse rating	………….Ampere
Size of conductor	……….mm
Monthly consumption (kWh)	...............kWh

5.7 For fossil fuels source

Types of fuel used	LPG (Cylinders)	Other ___________
Consumption per month		
Cost of fuel per unit		

6. Cost of technology

Technology	Initial cost	O&M cost	Life time (yrs)	Fuel cost
Traditional cookstove				
Improved cookstove				
LPG stove				
Briquette stove				
Biogas plant				
Induction stove				

Other (specify) ………………..				

7. User's perception

How satisfied are you with your current cooking technology ?			☐ Very satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐ Very dissatisfied
Questions	Yes	No	Remarks
Do you have any idea regarding the various tier of cooking solution?			
Do you think your cooking technologies causes any health problem for you family?			
Does your cooking technology produce smoke/indoor pollution?			
Do you think that your cooking technologies consumes less time for cooking?			
Do you think the fuel used by cooking technologies uses cheapest fuel available?			
Has your cookstove made cooking convenient?			

8. What kind of incentives will you prefer to shift to clean cooking especially induction stoves Please rank	• Reduced purchase cost
	• Subsidy on appropriate utensils used in induction stove
	• Loan programmes
	• Provide professional installation for free
	• Reduction in the NEA tariff
	• Availability of stable electricity
	• Easy access for utensils for induction stove
	• Easy process for shifting to 16A and above electric meters
	• Improvement in technology
	• Cooking training on induction stoves

Name of respondent: ………………………………	Signature : ………………..
Name of enumerator: ………………………………	Signature:…………….

Annex 2: Questionnaire for commercial sector

Water and Energy Commission Secretariat
Government of Nepal
Singha Durbar, Kathmandu
Present status and future plan of clean cooking technologies in major cities of Nepal

Commercial Sector

Inspection no.: **Date:**

1. Information of respondent & location

Name of respondent: ===============================
Position: =============================== Contact number: ===============================
District: Morang Metropolitan: Biratnagar Ward number: Name of the tole:

2. General information of the organization

2.1 Organization Information

Name of institution:	Establishment Date:
Institution categorization ○ Institutional canteen ○ Hotel and restaurants ○ Party palace and banquet ○ Hostel and Barrack ○ Others=========================	
2.2 Information about Building	**2.3 Institutional information**
Number of rooms …………………. Number of floors ……………… Floor area of institute ……………sq. ft. Building ownerships ○ Private/Rented ○ Government ○ Commercial building ○ Religious Building ○ Non-profit organization	No. of persons engaged in the institution ……… Operation days per year ……… Total capital ……… Approximate revenue generated in last year ……… Service capacity of institutions ……………
2.4 Type of kitchen ☐ Indoor without exhaust ☐ Indoor with exhaust ☐ Outdoor	

3. Technology and fuels

3.1 Please select the technology and fuels used	
Technologies ☐ Traditional cookstove ☐ Open stove ☐ Improved cookstove ☐ Husk cookstove	Fuels ☐ Fuel wood ☐ Agriculture residue ☐ Dung cake ☐ LPG

☐ LPG ☐ Briquette stove ☐ Biogas stove ☐ Furnace ☐ Induction ☐ Coil heater ☐ Others	☐ Briquette/coal ☐ Biogas ☐ Diesel ☐ Wax ☐ Electricity ☐ Solar ☐ Others
3.2 Size of stove (number of burners)	☐ Quantity of stove: ☐ Number of burners M

4. Energy supply for cooking technologies

4.1 For fuelwood energy source			
Source of Fuelwood	Forest	Own farm	Local market
Distance from source (km)			
Quantity of collection each time (Bhari)			
Time to collect the fuelwood (hr.)			
Frequency to collect/buy wood per month			
Cost to buy per bhari (NPR.)			

4.2 For agricultural residue energy source
Area of farm land ………………….. Quantity of agriculture residue produced …………………….

4.3 For animal dung energy source	
Number of livestock =================== Quantity of animal waste produced ………………..kg per day	
Do you make guinthaa?	Yes ☐ No ☐
Quantity of guitha	……………quintal per year

4.4 For biogas plant energy source	
Installed year	…………………
Capacity of plant (m^3)	…………………
Operating condition	Working ☐ Not working ☐

4.5 For briquettes energy source		
Source	Market	Domestic production
Quantity consumed per year (kg)		
Price (per kg)		

4.6 For electricity source	
Source	National Grid
Fuse rating	………….Ampere
Size of conductor	……….mm
Monthly consumption (kWh)	...............kWh

4.7 For fossil fuels source		
Types of fuel used	LPG (Cylinders)	Other ___________
Consumption per month		
Cost of fuel per unit		

5. Energy consumption for cooking

5.1 Non- electricity energy consumed for cooking per month							
Equipment	Fuel	Quantity per month	Time required for cooking (hours)			
			Morning	Afternoon	Evening	Others
Traditional cookstove	☐ Fuelwood ☐ Agricultural residue ☐ Dung cake					
Improved cookstove						
Husk cookstove	Husk					
LPG stove	LPG					
Briquette stove	Briquette					
Biogas stove	Biogas					

5.2 Peak operation time of electricity energy and equipment				
Equipment	Number	Peak operation time	Rating (Watt)	Hrs/day
Coil heater				
Hot plate				
Induction cookstove				
Rice cooker				
Electric kettle				
Oven				
Infrared cooking				
Electric pressure cooker				
Coffee maker				
Solar technologies				
Others specify				

5.3 Energy consumed for food and agro processing per month			
How many days do you process food per month? ………………days			
Technology	Quantity	Type of food processed	Time in hours
Traditional cookstove			
Improved cookstove			
LPG			
Briquette stove			

Biogas			
Induction stove			
Other (specify) ……………			

6. Cost of technology

Technology	Initial cost	O&M cost	Life time (yrs.)
Traditional cookstove			
Improved cookstove			
LPG stove			
Briquette stove			
Biogas plant			
Induction stove			
Other (specify) ………………..			

7. User's perception

How satisfied are you with your current cooking technology ?	☐ Very satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐ Very dissatisfied		
Questions	Yes	No	Remarks
Do you have any idea regarding the various tier of cooking solution ?			
Do you think your cooking technologies causes any health problem for you family ?			
Does your cooking technology produce smoke/indoor pollution?			
Do you think that your cooking technologies consumes less time for cooking ?			
Do you think the fuel used by cooking technologies uses cheapest fuel available ?			
Has your cookstove made cooking convenient?			

Are you interested in switching to any new technologies?	☐ Yes	☐ No
If No		

Why do you not want to shift ?	The current technology is ☐ Already good ☐ Cheaper ☐ Easy (To use and maintain) ☐ Fast cooking ☐ Safe and Reliable The new technology is ☐ Not readily available ☐ Too complex to use ☐ Unsafe ☐ Expensive ☐ Unavailability of compatible cookware ☐ I do not have information about this technology ☐ Lack of skill and infrastructure ☐ Lack of space ☐ Other ___________________
If Yes	
Why do you want to shift?	The old technology is ☐ Expensive ☐ Polluting (Smoke and Dust) ☐ Inconvenient (Use and Clean) ☐ Unsafe ☐ Time Consuming The new technology is ☐ Clean and Healthy ☐ Cheaper to use ☐ Convenient ☐ Other
Which technology would you like to shift to?	☐ Improved cookstove ☐ LPG ☐ Electric cooking___________________________ ☐ Biogas
What are the barriers that are stopping you from shifting?	☐ Difficult to obtain (fuel and technology) ☐ Lack of space ☐ Unreliable infrastructure ☐ Initial Cost (stove and utensils) ☐ Unreliable ☐ Lack of knowledge (use and maintain) ☐ Lack of awareness about the negative impacts of traditional cooking ☐ Traditional values
What kind of incentives will you prefer to shift to clean cooking especially induction stoves Please rank	☐ Reduced purchase cost

	☐ Subsidy on appropriate utensils used in induction stove ☐ Loan programmes ☐ Provide professional installation for free ☐ Reduction in the NEA tariff ☐ Availability of stable electricity ☐ Easy access for utensils for induction stove ☐ Easy process for shifting to 16A and above electric meters ☐ Improvement in technology ☐ Cooking training on induction stoves

What do you think you will be using in five years ?

Ten years ?	Ten years ?	Fifteen years?
☐ Only LPG	☐ Only LPG	☐ Only LPG
☐ LPG and electricity	☐ LPG and electricity	☐ LPG and electricity
☐ Only electricity	☐ Only electricity	☐ Only electricity
☐ Others	☐ Others	☐ Others

Name of respondent : ………………………………	Signature : ………………..
Name of enumerator : ………………………………	Signature:…………….