GOVERNMENT OF NEPAL
WATER AND ENERGY COMMISSION SECRETARIAT
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FINAL REPORT

PRESENT STATUS AND FUTURE PLAN OF CLEAN COOKING TECHNOLOGIES IN KATHMANDU VALLEY

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EXECUTIVE SUMMARY

Introduction

Nepal has huge potential of electricity and renewable energy. which be utilized in cooking sector. The traditional fuel and imported Liquefied petroleum gas (LPG) are dominant for cooking in residential as well as commercial sectors of Nepal. The preliminary objective of this assignment is to investigate the status of clean cooking technology used in four clusters, i.e., Kathmandu Metropolitan City, Lalitpur Metropolitan City, cluster 3 (which includes Budhanilikantha, Tarkeshwor, Chandragiri, Tokha, Kageshwari Manohara, Nagarjun, Kirtipur, Dakshinkali, and Shankharapur municipalities), and cluster 4(Which includes Bhaktapur, Changunarayan, Madhyapur Thimi, Suryabinayak, Mahalaxmi, Godawari municipalities and Konjyosom, Bagmati, and Mahankal rural municipalities) . This study has been conducted for residential and commercial sectors of each cluster. In residential sector, households were considered as sample units whereas commercial entities were considered as sample units for commercial sector. The primary data was collected in the form of interviews through structured questionnaires. The questionnaires were designed in order to inform about socioeconomic information, existing cooking status, willing of switching possibilities, cost of fuel and technologies, obstacles and indoor pollution. The data collected was analysed and energy model was designed to investigate the future possibilities of switching of cooking mechanism by cleaner version of technologies. The cost and emission for different cooking fuel resources and technologies have been calculated. The study further aimed to forecast the different energy demand scenarios for different cooking technologies with business as usual (BAU) and switching of cooking technologies for the upcoming 20 years in 5-year step.

Cooking technology in Nepal

Energy consumption in Nepal is still dominated by traditional fuel for cooking i.e. many people living in Nepal are using fuelwood, agricultural residue and dung cake as their primary source of fuel. According to annual household survey 2017, 52.4% of household are still using fuelwood as primary source of fuel where, 65.8% of households in rural area and 54.1% household in urban area are using fuelwood as primary source of fuel. While in Koshi province and Madesh Province, the share of traditional energy for cooking was determined to be 82.91% and 91.28% respectively (WECS, 2021) which shows that clean cooking technology is still challenging in many sector of Nepal. In commercial sector of Koshi province and Madesh province, the proportion of fuelwood being used are 58.78% and 1.23% respectively. According to census 2011, the share of fuelwood in Pokhara and Butwal was 21.53% and 21.57% while, the share of LPG was 71.63% and 73.63% respectively. In Nepal, 82.90% of households are using single cook stove and 16.40% are using two type cook stove while remaining are using three and more type cook stove (World bank, 2019).

Clean cooking

In context of Nepal, LPG stove, electric cookstove, biogas, improved cookstove etc. and tire 3 and above cooking appliances are considered as clean cooking appliances. The commonly used clean cooking stoves in Nepal are LPG stove, biogas, ICS, and electric stoves. To minimize the use of traditional cookstove in Nepal, government has been promoting improved cooking solutions. On the other hand, Alternative Energy Promotion Center (AEPC) has prioritized the use of cook stove that emits much lower Carbon Dioxide (CO_2). The Government of Nepal has developed different policies and targets to penetrate electricity as primary cooking technology. According to the Second National Determined Contribution (NDC) and Sustainable Development Goal (SDG) 25% of households by 2030 use electricity as the primary source for cooking purpose and ensure access to affordable, reliable, sustainable and modern energy for all sector including cooking.

Survey design and sample determination

The project is conducted within the borders of the Kathmandu Valley. The location of the project is further divided into different clusters as per the requirement of the assignment. The study is conducted for both residential and commercial sectors of each clusters. Similarly, the study shall be conducted for residential and commercial sectors. Kathmandu Valley consists of the three districts namely Kathmandu, Bhaktapur and Lalitpur and has a population and households of 3,035,941 and 787,725 respectively. Similarly, there are 104,664 food and accommodation entities as categorized by national standard for industrial categorization (NSIC). The size of households and entities in cluster 1 was 231714 and 13015 respectively, in which the sample size was 403 and 392 respectively. Similarly, the size of households and entities in cluster 2 was 77872 and 2856 respectively, in which the sample size was 402 and 356 respectively. Similarly, the size of households and entities in cluster 3 was 306202 and 8879 respectively, in which the sample size was 403 and 387 respectively. Similarly, the size of households and entities in cluster 4 was 171587 and 4898 respectively, in which the sample size was 403 and 375 respectively.

Before the survey, questionnaires were prepared and one-day training was conducted for enumerators to familiarize them with the data collection procedures. A pretesting was carried out using few household and entities sample to test the questionnaire developed before performing the survey. While undertaking the survey, continuous monitoring of the collected data was done and feedbacks and guidelines by the core team regarding the collected data was incorporated.

Cooking in Kathmandu Valley

Residential sector

In residential sector of Kathmandu valley, 97.39% of the households use LPG stove while rice cooker is used by 25.09%, biomass cookstove by 13.42%%, and electric stove by 10.19%. On the basis of fuel, 97.39% of household use LPG, 43.54% use electricity, and 13.42% use fuelwood as the source of fuel for cooking. Regarding stove stacking, 47.79% of household use single type stove, 37.40% use two type stoves while the remaining percentage of household use more than three type stoves. Also, 13.25% of the households used LPG with rice cooker while about 6.35% used biomass stove with LPG. During the survey, it was found that 54.51% of the respondents considered their current cooking technology to be expensive. Furthermore, 16.60% of the participants expressed concerns about the potential risk of accidents associated with their current cooking technology. While assessing the willingness to switch during the survey, about 72.36% of the households were in favour of switching to cleaner technologies. The major barriers towards shifting were identified as unreliability of electricity along with the low fuse rating used in most of the households. For using electrical cook stove, fuse rating should be higher but in case of residential sector, 19.88% of household are still using 6 A fuse.

Commercial sector

In commercial sector of Kathmandu valley, 96.03% of commercial entities are using LPG for cooking while 14.04% of commercial entities use electric cook stove, also, electric kettle, rice cooker, and biomass cookstoves were used by 10.86%, 11.66%, and 6.62% entities respectively. In regards to cooking fuels, 96.03% of commercial entities use LPG while electricity, and fuelwood is used by 35.17%, and 6.62% of commercial entities respectively. Among the commercial entities 62.25% uses single stove, 27.22% entities use two type stove and the remaining percentage of entities use three or more type stove. On the other hand, 60.07% use one type fuel while 35.56% use two type fuel and the remaining percentage of commercial entities use more than two type fuel for cooking. Since, most 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 29.21% of the share. During the survey, 32.05% of the respondents regarded their cooking technology as time consuming. Further, it was found that 24.42% and 23.96% of the respondents considered their current cooking technology expensive to maintain and operate. While assessing the willingness to switch during the survey, 57.48% of the households were in favour of switching to cleaner technologies. Most of the respondents who were not willing to shift towards new technology has issues with the compatibility aspects of utensils with new cooking technologies. The major barrier on shifting towards electric cooking technology is fuse rating as for using electrical cook stove, fuse rating should be higher but in case of commercial sector, 3.51% and 39.40% of the entities were using 6A and 16A fuse respectively.

Energy consumption of Kathmandu valley

The heat energy obtained from the combustion of various fuels is used for cooking. However, different factors like incomplete combustion of fuels, poor heat retention in cooking areas, and external environmental factors affect the efficiency of fire-based cooking technologies. Further, in electrical cooking equipment copper loss incurred due to coil heating during cooking causes its efficiency to drop. For the analysis, the efficiency of LPG and biomass-based fuel is considered to be 48% and 15% respectively. Further, since the efficiency of a cook stove is based on heat transfer only, and considering the losses, the efficiency of electricity as cooking fuels is taken as 90%. The total final energy consumed in the residential area of Kathmandu Valley is found to be 6735.96 TJ while the total useful energy consumed is found to be 2727.5 TJ. The specific energy per capita was found to be 2.23 GJ/Capita. Similarly, the total final energy consumed in the commercial areas of Kathmandu Valley is found to be 3194.33 TJ while the total useful energy consumed is found to be 1495.65 TJ. The specific energy per entity was found to be 107.34 GJ/Entity.

Energy demand forecasting

For forecasting, business as usual (BAU) and shifting scenario has been developed. In BAU the trend of cooking fuel is assumed to be same for the upcoming year while the shifting scenario is developed on the bases of Nepal's Long-term Strategy for Net Zero Emission plan.

In residential sector of Kathmandu valley, for the BAU scenario, the energy demand is expected to be 6942.39 TJ for year 2025. Further, in years 2035 and 2045 the energy demand is expected to reach 7889.08 TJ and 8617.48 TJ respectively. For the shifting scenario, the energy demand is expected to be 6419.38 TJ for year 2025. Further, in years 2035 and 2045 the energy demand is expected to reach 5180.97 TJ and 4335.60 TJ respectively.

In commercial sector of Kathmandu valley, for the BAU scenario, the energy demand is expected to be 3121.02 TJ for year 2025. Further, in years 2035 and 2045 the energy demand is expected to reach 3740.21 TJ and 4078.62 TJ respectively. For the shifting scenario, the energy demand is expected to be 3121.02 TJ for year 2025. Further, in years 2035 and 2045 the energy demand is expected to reach 2654.99 TJ and 1911.42 TJ respectively.

Comparative analysis and conclusion

On the basis of this study, although Kathmandu Valley as a whole uses different types of stove for cooking, all clusters consume LPG the most as it is easily accessible but are showing their interest to shift towards electricity. The percentage of households using electric cook stove was highest in cluster 4 for residential sector and in cluster 1 for commercial sector. The use of electricity was highest in Kathmandu Metropolitan City in both residential and commercial areas of Kathmandu Valley. The percentage using electricity should be increased as there are many benefits using electricity as fuel for cooking. Also, most of the household sectors of both cities are willing to change their cooking technology into electricity after certain years. In residential areas, the most households regarded their cooking technology as expensive. The higher price of LPG might have influenced this response. Whereas in commercial sector, the time efficiency and space efficiency of the cooking technology were more problematic. Furthermore, the major barriers for switching to clean technologies were also assessed. The main barrier is fuse rating as most of the households and some commercial entities are still using 6A fuse, therefore, the connection line should be upgraded to at least 16 A and the transmission and distribution line should also be upgraded. Along with this, the financial incentives such as reduction in value added tax (VAT) and custom duty should be provided so that the consumers get motivated to use clean source of energy for cooking.

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LIST OF ABBREVIATIONS

AEPC	Alternative Energy Promotion Centre
BEST	Biomass Energy Strategy
BAU	Business As Usual
CBS	Central Bureau of Statistic
CO	Carbon Monoxide
DoI	Department of Industry
EIA	Environment Impact Assessment
FY	Fiscal Year
GoN	Government of Nepal
GWh	Gigawatt hour
ICS	Improved Cook Stove
ktoe	Kilo tonnes of oil equivalent
LPG	Liquefied Petroleum Gas
MAED	Model For Analysis of Energy Demand
MECS	Modern Energy Cooking Services
MTF	Multi-Tier Framework
MW	Mega Watt
NEA	Nepal Electricity Authority
NPC	National Planning Commission
NSIC	National Standard Industrial Classification
PM	Particulate Matter
RFP	Request for Proposal
RETs	Renewable Energy Technologies
TCS	Traditional Cook Stove
TOR	Terms of Reference
UNEP	United Nations Environment Program
WECS	Water and Energy Commission Secretariat
WHO	World Health Organization

CHAPTER 1:INTRODUCTION

1.1 Background

The energy consumption in Nepal is still dominated by traditional fuels with more than 66.26% of its share in the overall energy consumption in 2021. The use of traditional fuels is especially high in residential and commercial sector at 84.87% and 52.48% respectively. The large share of the traditional fuels is especially due to the use of solid biomass and loose biomass for cooking in residential sector and commercial sector[1]. The use of traditional fuels especially in inefficient cooking technologies has caused severe health problems especially for women and children residing in Rural area. World Health Organization (WHO) estimates that in Nepal around 8,700 especially women's and children die prematurely due to the indoor pollution caused by the biomass burning[2]. In addition, the import of the large quantities of liquefied petroleum gas (LPG) has created an unnecessary burden on the country economy. Currently, the Nepal Oil corporation is facing a deficit of NPR 277 (December 2022) per cylinder of the LPG gas[3]. This has caused a serious impact on the energy security of the country.

Nepal with its large reserves of water resources has the capacity to generate huge amount of electricity. Water and Energy commission secretariat has further determined that the country has the capacity to generate 73GW of electricity[4]. Similarly, Nepal with its agricultural dependent economy and warm weather in low lands has the best possible condition for the generation of biogas which can be used for cooking. The proper utilization of the locally available fuel substitute can further enhance the energy security of the country while decreasing the economic burden towards the imported fuels.

The Water and Energy Commission Secretariat (WECS) was established in 1975 under Government of Nepal with the objective to develop the water and energy resources in a unified and accelerated manner. It has been engaged in conducting field surveys to collect energy resources and consumption data and information from primary sources of different energy consuming sector. Further, WECS has been preparing the status report and future plan for cooking technologies and fuels throughout Nepal. In this regard, WECS has launched an assignment namely, "Present status and future plan of clean cooking technologies in Kathmandu valley.

1.2 Objectives

The main objective of the assignment is to find out the present status of cooking technologies and prepare the future plan of switching to cleaner cooking technologies in Kathmandu valley. The study shall be conducted in Kathmandu valley i.e., Kathmandu, Bhaktapur and Lalitpur districts. The specific objectives are:

- To find out the present status of different cooking technologies used in the residential and commercial sectors
- To prepare detail survey questionnaire in consultation with client along with determination of sample size and sample location
- To find out the future possibilities of switching to cleaner version of cooking technologies

[1] https://wecs.gov.np/source/Energy%20Sector%20Synopsis%20Report%2C%202022.pdf
[2] https://cdn.who.int/media/docs/default-source/country-profiles/health-impact-assessment/hia-npl-2004-country-profile.pdf?sfvrsn=a4b94a06_7&download=true
[3] http://noc.org.np/fortnightly
[4] https://www.wecs.gov.np/storage/listies/February2021/final-report-july-2019-on-hydropower-potential.pdf

- To calculate and compare the costs i.e. base cost and running cost and emission of different cooking fuel resources and technologies
- To find out the constraints and barriers for switching to cleaner form of cooking technologies
- To analyze and forecast the energy demand for different cooking technologies in business as usual (BAU) and after switching to cleaner cooking technologies for upcoming 15 years in 5 years interval
- To recommend the policy briefs for decision makers/planners

1.3 Scope of work

The assignment will be carried out systematically using appropriate methods and methodology in Kathmandu valley. The scope of work in order to fulfil the consulting assignment as indicated in Request for Proposal (RFP) include

- Review of different plans, policies and documents prepared by the institutions within the country and delivery partners related to the assignment
- Preparation of detailed questionnaire for residential and commercial sector in consultation with WECS
- Determination of sample size at 95% level of confidence, 5% margin error and at 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 of switching to clean cooking technologies
- Gap analysis to identify the barriers and constraints in switching to cleaner form of technologies
- Identification of the cost and emission parameters related to different cooking technologies and cooking fuel resources
- To calculate the energy demand for various scenarios for different cooking technologies with BAU and switching of technologies for upcoming 15 years in 5-year step
- To benchmark the technical requirement for the use of electric cooking technologies and accordingly develop the investment cost to shift to clean cooking technologies
- To develop policy brief and incorporate in the final report

CHAPTER 2:LITERATURE REVIEW

2.1 Energy situation of Nepal

The energy consumption in Nepal is continuously increasing and has reached 621 PJ in the year 2021. The overall energy consumption in Nepal is dominated by the traditional fuels at 66.26% followed by commercial fuels at 31.34% ad renewable fuels at 2.40%. Similarly, in regards to different economic sectors, residential sector is the highest energy consuming sector at 63.2% followed by the industrial sector at 18.3%. The consumption of the traditional fuels is especially high in the residential sector and commercial sector due to the burning of biomass for cooking and heating purposes. Overall, 84.87% and 52.48% of the energy consumed in the residential and commercial sector is due to the burning of traditional fuels including biomass, dung cake and agricultural residue[5].

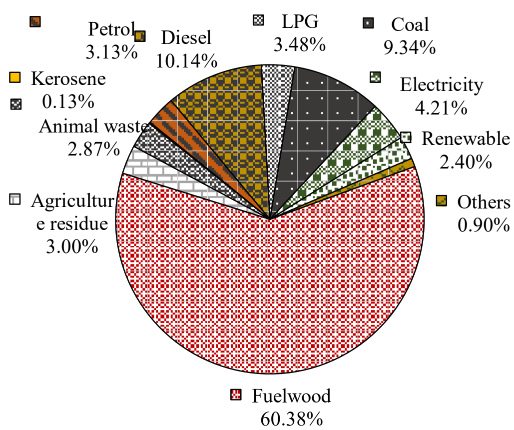


Figure 2.1: Energy consumption by fuel types

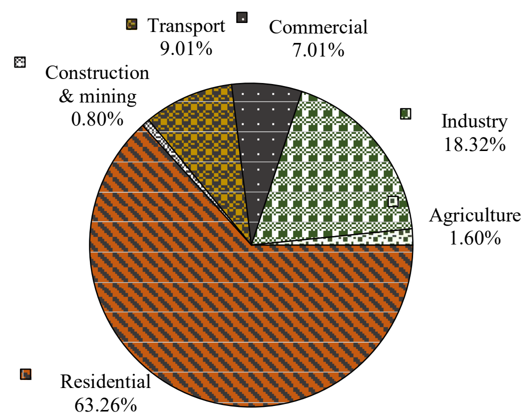


Figure 2.2: Energy consumption by economic sector

2.2 Cooking fuels in Nepal

In Nepal, fuelwood is the major source of energy used for cooking. However, in urban areas the use of LPG is predominately used fuel for cooking. According to the annual household survey conducted by central bureau of statistics (CBS) in 2017, 52.4% of the households in Nepal uses fuelwood as the primary cooking fuel followed by LPG at 33.1%. Similarly, the share of animal waste and agriculture residue in cooking is 8.5% and 2.7% respectively. In regards to the urban areas 54.1% of the household are using LPG for cooking followed by 35.4% of the households using fuelwood. Although LPG can be considered as a clean fuel, but as an imported fuel it always has supply risk and macroeconomic concern. The details of fuels used for cooking in Nepal is shown in Figure 2.3.

[5] https://wecs.gov.np/source/Energy%20Sector%20Synopsis%20Report%2C%202022.pdf

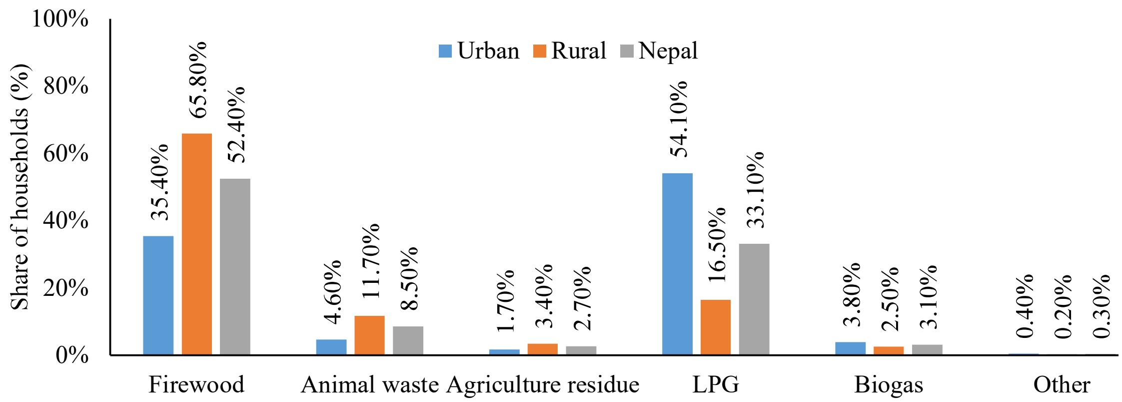
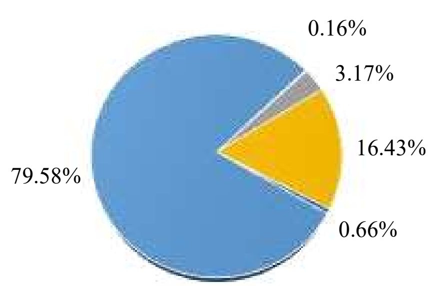
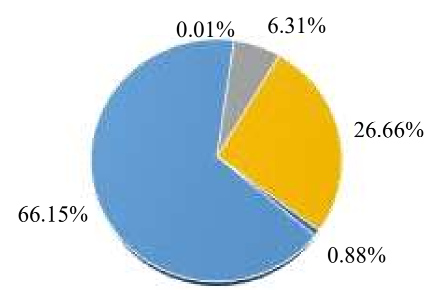


Figure 2.3: Energy consumption by fuel types in 2017[6]

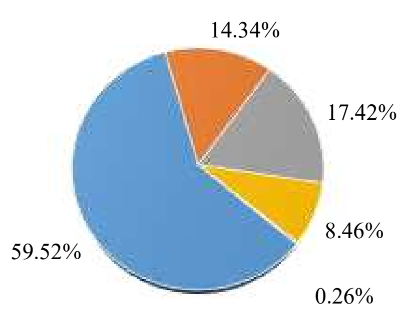
The study conducted by WECS entitled “Energy consumption and supply situation in federal system of Nepal” further highlights the sectoral energy consumption by fuel types and end use. The report further highlights the dependency on fuelwood and LPG for cooking in Province 1, Madesh Province and Bagmati Province. The share of traditional energy for residential cooking in Province 1, Madesh province and Bagmati province are 82.91%, 91.28% and 69.23% respectively while the share of LPG in the respective provinces are 16.43%, 8.46% and 29.54% respectively.



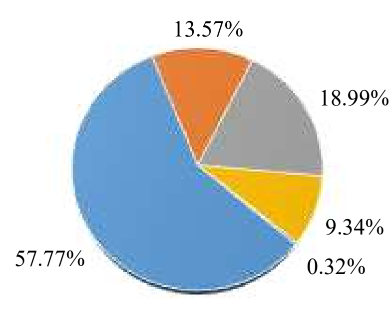
a. Province 1 (Overall)



b. Province 1 (Urban)

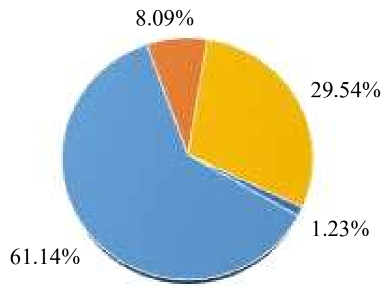


c. Madesh Province(Overall)

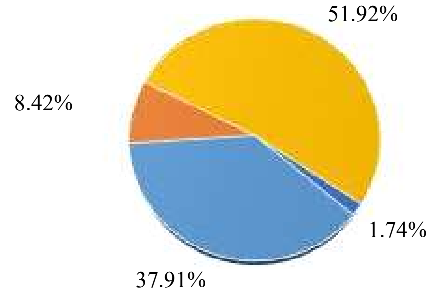


d. Madesh province (Urban)

[6] https://cbs.gov.np/wp-content/upLoads/2019/01/Annual-Household-Survey-2016_17.pdf



e. Bagmati Province(Overall)



f. Bagmati province (Urban)

Fuelwood Agriculture residue Animal waste LPG Other

Figure 2.4: Energy consumption for cooking in residential sector[7]

Similarly, LPG is predominant source of cooking fuels used in commercial sector in Madesh province and Bagmati province. In case of Province 1, traditional fuels still dominate the share for cooking fuels. The proportion of fuelwood and LPG in total energy consumption for cooking in commercial sector of province 1 is 58.75% and 40.82% respectively. Similarly, in Madesh province the energy consumption for cooking in commercial sector by LPG and fuelwood is 94% and 1.23% respectively. In case of Bagmati Province, the share of LPG and traditional fuels is shown in Figure 2.5.

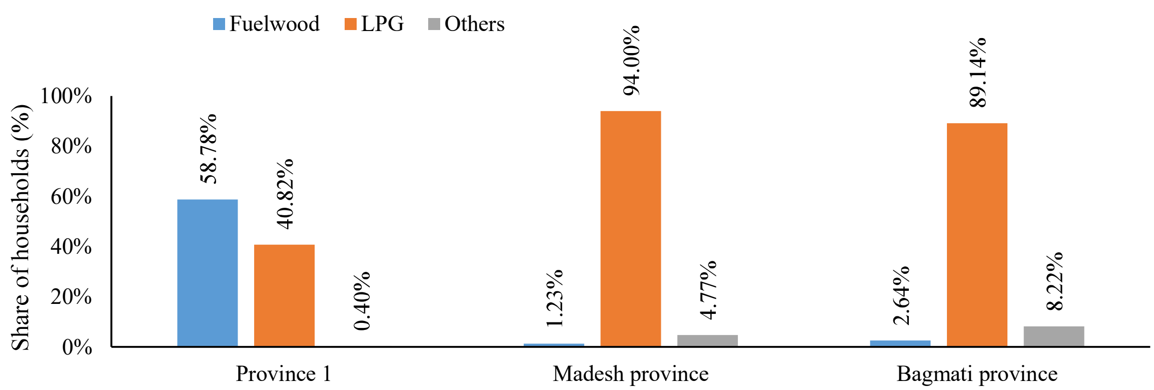


Figure 2.5: Energy consumption for cooking in commercial sector[8]

2.3 Cooking stoves

According to the Multi-Tier Framework 2019 published by World Bank Group, based on 6000 samples data collected throughout the country distributed proportionally based on physiographical region, traditional cook stoves lead the way with use in 47.6% of household followed by the use of LPG stove and open fire stove at 26.3% and 15.1% respectively. Proportion of various cook stoves used in the households of Nepal is presented in Figure 2.6

[7] https://wecs.gov.np/pages/reports-and-publications?lan=en&id=107
[8] https://wecs.gov.np/pages/reports-and-publications?lan=en&id=107

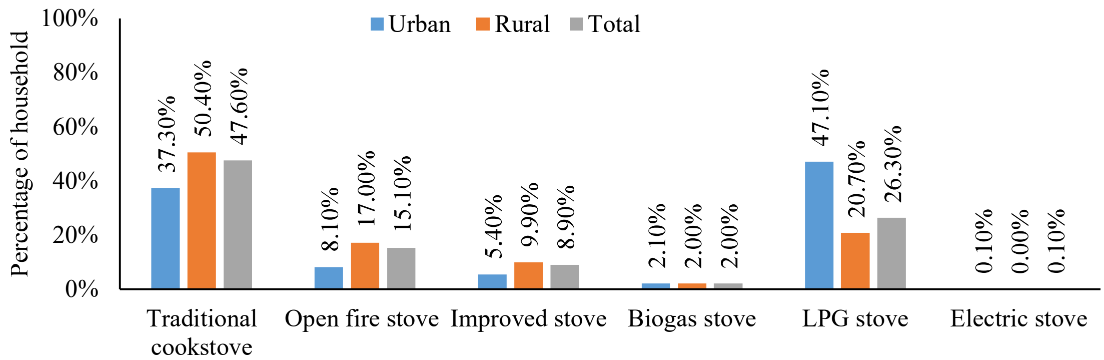


Figure 2.6: Cook stoves used in Nepal

The process of using more than one type of cook stoves is called stove staking. Most of the households in Nepal use only one type of stoves for cooking while few households use two and more type of cooking solution. According to the Multi-Tier Framework 2019, 82.9% of the household use single cook stoves while 16.4% and 0.7% of the households use two and three types of cook stoves respectively. Similarly, 7.2% of the household use the combination of traditional cook stoves and LPG followed by 2.7% household using open fire and LPG. The details of the stove stacking is shown in Figure 2.7.

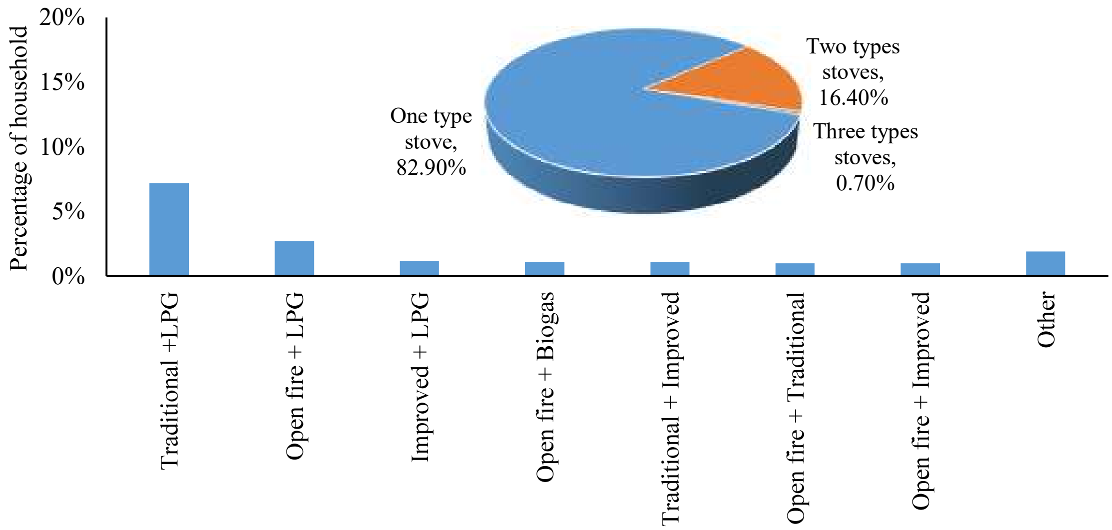


Figure 2.7: Stove stacking, combination of stove[9]

2.4 Clean cooking technology

Any type of cook stove is considered "Clean" if its emission meets WHO Guidelines. Currently, available options that are clean at point-of-use include electricity, gas, ethanol, solar, and the highest performing biomass stoves. The Guidelines discourage household use of kerosene and unprocessed coal in the home, due to significant health risks from these fuels. Various technologies like improved cook stove, biogas, induction stove etc. is considered as

[9] https://microdata.worldbank.org/index.php/catalog/3532

clean cooking solutions in Nepal. The efficiency of various tiers of cook stoves are presented in Table 2.1.

Table 2.1: 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)

Cooking without clean stoves and fuel releases toxic pollutants into the environment and endangers the health and well-being of billions across the globe. Open fires and inefficient stoves create indoor pollutant which can cause health hazards especially to women and girls in the case of Nepal. The use of inefficient stove in cooking emits carbon monoxide and carbon which contributes to climate change.

2.5 Emissions Scenario

Energy use and consumption emits more GHGs worldwide than any other anthropogenic activities. Burning fossil fuels such as coal, oil and natural gas converts carbon in the fuel to carbon dioxide (CO_2), the predominant gas contributing to the greenhouse effect. The energy sector includes all fuel combustion-related emissions from energy industries, manufacturing and construction, transport and other source categories. Energy efficiency improvement and fuel-switching from fossil fuels to electricity in transport, residential/domestic, commercial and agriculture sectors offer deep decarbonization to achieve net zero target.

According to the International Energy Agency (IEA), global energy-related CO_2 emissions in 2019 were 3.3 billion tonnes of which 33% contribution were from the advanced economies and the remaining from the rest of the world. In 2019, developed countries observed a decline in their CO_2 emission by 3.2% from the 2018 level whereas there was still 2% growth in emission from the rest of the world during the same period. Nepal has set its goal to achieve net zero emissions by 2045. However, the energy sector related CO_2 emissions in 2019 is shown in Table 2.2. The total GHG emission in 2019 was 17.18 CO_{2eq}. In Nepal, the residential sector contributes to the majority of the emissions at 35.33%. The majority share of the emissions from the residential and commercial sector can be contributed to the biomass burning. Hence use of alternative fuels for cooking can significantly reduce the overall emission of Nepal.

Table 2.2: Emission in Nepal from energy sector, 2019[10]

Sectors	Emissions in million metric tonnes			
	Methane	Nitrous Oxide	Carbon dioxide	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**

2.6 Barriers for shifting to electric cooking

The study conducted by WECS namely, "Status of clean energy cooking technologies used in two major cities of Nepal" has highlighted the major barriers based on the user response for the promotion of clean cooking technologies. The major barriers identified for the promotion of electric cook stove are high cost of electricity along with unstable electricity, frequent power cut and lack of reliability of the latest technologies in both residential and commercial sector in Nepal.

The funding proposal prepared by the Alternative Energy Promotion Centre (AEPC) namely, "Mitigating GHG emission through modern, efficient and climate friendly clean cooking solutions (CCS)" lists out the major barrier for the promotion of clean cooking technologies[11]. These barriers are

- Socioeconomic barriers: Consumer's limited awareness about benefits of clean cooking solutions (CCS) and subsidy policy on renewable energy and their low willingness to pay higher prices due to low economic levels of the household
- Technological barriers: Low level of technical knowledge and unavailability of technicians is another major constraint to shift towards CCS; Access to grid electricity, quality of electricity power supply and voltage fluctuations are other challenges to shift towards electric cooking
- Financial barriers: Lack of ability to pay for technologies and fuel prices amongst the TCS user.
- Institutional barriers: Lack of institutional setup for the promotion of renewable energy technologies in provincial and local government

Further Ministry of Forest and Environment has highlighted peak load management. Limited power rating of electrical meters, lack of awareness, perception in high risk in investment etc are the major obstacles for the promotion of electric cookstoves in its study "Assessment of Electric Cooking Targets for Nepal's 2020 Nationally Determined Contributions (NDC)"[12].

2.7 Policies and document review

The Government of Nepal along with various development partners has prepared various reports and documents for the promotion of clean cooking technologies in Nepal. Further, with the recent trend to shift towards the electric cooking the Government of Nepal has further specifically targeted electric cooking while preparing various plans and policies.

[10] https://www.mofe.gov.np/uploads/documents/nepal-lts-document-uploaded-in-unfccc1653986846pdf-0523-253-1657876086.pdf
[11] https://www.greenclimate.fund/sites/default/files/document/funding-proposal-fp172.pdf
[12] https://www.mofe.gov.np/uploads/documents/e-cooking-assmntndc-20201623998059pdf-3367-307-1658827919.pdf

2.7.1 Second Nationally Determined Contribution[13]

As mandated by the Paris agreement, the Government of Nepal has prepared the Nationally Determined Contribution (NDC) in 2016 and submitted to the United Nations Framework Convention on Climate Change (UNFCCC). It further updated the targets of the NDC and submitted the Second NDC to UNFCCC in 2020. The document specifically targets the promotion of the clean cooking technologies to decrease the emissions in Nepal. The target of the Government of Nepal based on its second NDC include

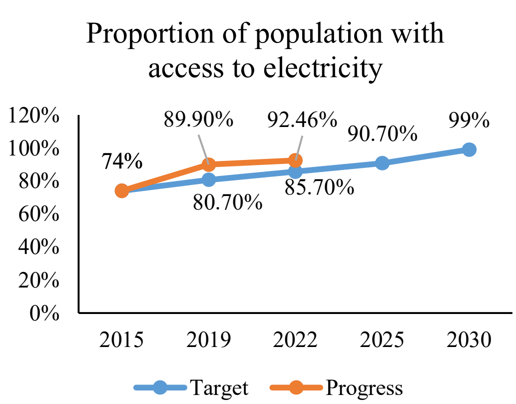
- By 2030, ensure 25% of households use electric stoves as their primary mode of cooking.
- By 2025, install 500,000 improved cookstoves, specifically in rural areas.
- By 2025, install an additional 200,000 household biogas plants and 500 large scale biogas plants (institutional/industrial/ municipal/community)

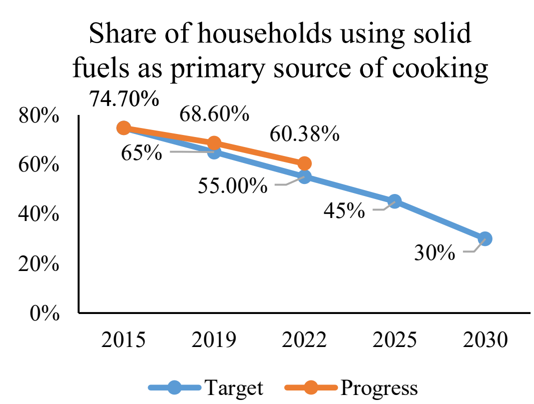
These targets can reduce emission about 11% in 2025 while 23 % in 2030.

2.7.2 Sustainable development goals

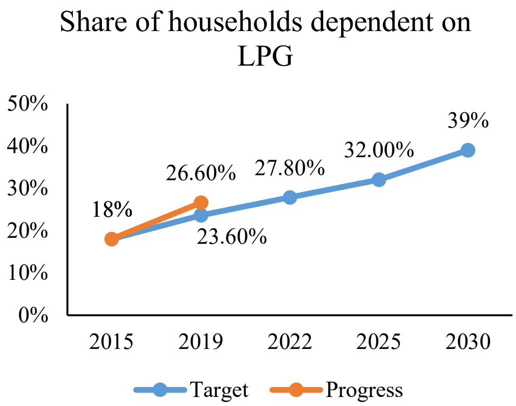
The Government of Nepal has prepared the roadmap for achieving the SDG targets by 2030. The SDG 7, specifically focuses on the promotion and availability of the clean energy and modern energy while improving the overall energy efficiency within the country. The SDG7 targets include achieving, by 2030, (i) universal access to affordable, reliable and modern energy services, (ii) increasing substantially 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 primary source of cooking from 74.7% in 2015 to 45% in 2025 and 30% in 2030
- Increase the share of household's 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 residential and commercial sector from 10% in 2015 to 40% and 60% in 2025 and 2030 respectively





[13]https://climate.mohp.gov.np/attachments/article/167/Second%20Nationally%20Determined%20Contribution%20(NDC)%20-%202020.pdf



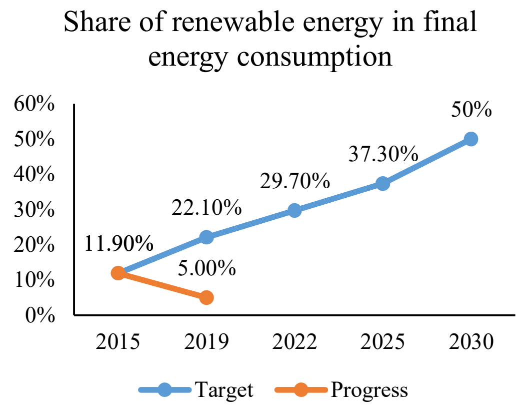


Figure 2.8: Targets of SDG 7 and progress made

SDG had set the target to provide electricity access to 85.7% of people within 2022 and 99% of people within 2030. According to the progress report 2022, the target is being met and 92.46% of people have been able to get electricity access within 2022. Similar results can be seen for other targets of the SDG. From the graph showing the share of renewable energy in final energy consumption, it may appear that the consumption of renewable energy is decreasing but the situation is not as it appears. The decrease in the consumption of renewable energy is seen because the initial value of 11.9% (2015) includes hydroelectricity as well but the later value of 5% (2019) does not include hydroelectricity. So, even though the curve shows decrease in consumption of renewable energy, the consumption is actually increasing.

2.7.3 Long term strategy for net zero emission

Long term strategy for Net zero emission has been prepared with the ambitious target to achieve the net zero carbon emissions by 2045. It further projects the emissions in different scenario and develops the emission reduction that can be achieved through various strategic action. The various strategic actions in residential sector includes

- 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 in with additional measures as compared to the reference scenario. Similarly, total electrification in all commercial sector has the potential to achieve 100% emission reduction by 2030.

2.7.4 Assessment of Electric Cooking Targets for Nepal's 2020 Nationally Determined Contributions (NDC)

The Assessment of Electric Cooking Targets for Nepal's 2020 Nationally Determined Contributions (NDC) published by the Ministry of the Forest and Environment assess the targets related to the electric cooking as mentioned in the second NDC and develops the recommendation for timey achievement of these targets. The recommendations include

- Ensure affordable supply of quality electric cooking products (providing financial incentives, encourage domestic production, develop standards etc.)

- Ensure reliability of electricity supply at household level (upgrading the distribution system, energy meter, house wiring etc.)
- Ensure adequate planning and promotion measures (awareness to local government and public, development of market-based policies and encouraging the private sectors

2.7.5 15th Five Year Periodic Plan

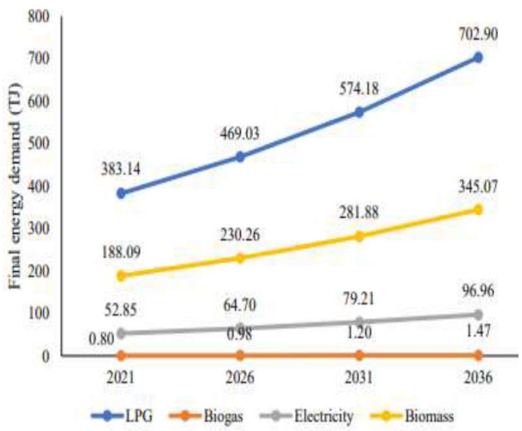
The plan has a vision to achieve the SDGs and to promote green economy through adaptation and mitigation of impacts of the greenhouse gases on the environment are the present needs. The plan has set the strategy and working policy to utilize the locally available resources for the promotion of renewable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

- Increase the per capita electricity consumption from 245 kWh in 2018/19 to 700 kWh in 2023/24
- Increase the share of renewable energy from 7% in 2018/19 to 12% in 2023/24 and decrease the share of solid fuels from 69.3% in 2019/20 to 50% in 2023/24.

The 15th periodic plan has further targeted to install an additional 200,000 household biogas plants and 500,000 improved stoves and gasifiers (thermal electric technology). Further it has aimed to increase the production of the Bio-briquette pellet at the rate of at least 20,000 MT per year. Similarly, it has further aimed to substitute 40,000 MT of LPG through the installation of 500 high capacity biogas plant.

2.7.6 Status of Clean Energy Cooking Technologies used in major cities of Nepal (Pokhara and Butwal)

Water and Energy Commission Secretariat conducted the study to access the status of clean energy cooking technologies used in Pokhara and Butwal. The report document provides information about the types and proportion of cooking technologies used in residential and commercial sector of two major cities of Nepal, i.e., Pokhara and Butwal. The report further projects the energy consumption in both sectors up to the year 2036. The summarized data from the report can be seen in Figure 2.9 and Figure 2.10.



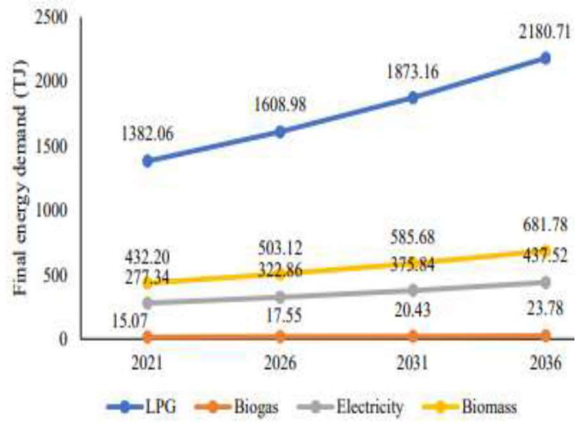


Figure 2.9: Total energy demand projection for cooking in Butwal

Figure 2.10: Total energy demand projection for cooking in Pokhara

Furthermore, the report also provides information about the hierarchy of cooking technologies being used.

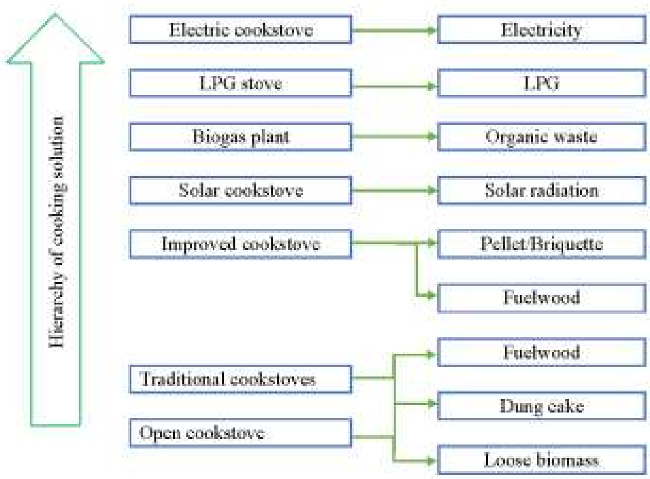


Figure 2.11: Hierarchy of cooking solutions(WECS, 2022)

2.8 Energy Modelling Tools

For modeling the future demand, different modeling tools can be use. Some of the modelling tools are LEAP (Low Emissions Analysis Platform), MAED (Model for Analysis of Energy Demand) etc. For the modeling database is generated for a base year. This includes energy consumption, supply and resource assessment and then the future energy demand is forecasted.

2.8.1 Model for Analysis of Energy Demand (MAED)

MAED is one of the energy modelling tools developed by the IAEA (International Atomic Energy Agency). MAED model evaluated future energy demand based on medium to long term scenarios for socio-economic, technological and demographic developments. The starting point for using the MAED model is construction of base year energy consumption. This requires compiling and reconciling necessary data from different sources, deriving and calculating various input parameters and adjusting them. Then in next stem, the future scenario is developed viewing the country situation and objectives.

The model focuses exclusively on energy demand, and even more specifically on demand for specified energy services. The various energy forms, i.e., electricity, fossil fuels, and renewable energy would compete for a given end-use category of energy demand. This demand is specifically calculated in useful energy terms and then converted into final energy, taking into account the market penetration rates and the efficiency of each alternative energy source, both specified as scenario parameters. Non-substitutable energy uses such as motor fuels for cars, electricity for specific uses (electrolysis, lighting etc.) are calculated directly in terms of final energy.

2.8.2 Low Emission Analysis Platform (LEAP)

LEAP is a transparent and user-friendly tool for energy and climate mitigation planning that has been adopted by many organizations. It is distributed and supported by Stockholm Environment Institute (SEI) through LEAP web site. It is a powerful, versatile software for integrated energy planning and climate change mitigation assessment. It also calculates the benefits after reduction in emissions.

LEAP is an integrated, scenario-based modelling tool that can be used to track energy consumption, production and resources extraction in all sectors of an economy. It is a medium to long term modelling tool. LEAP supports a wide range of different modelling methodologies: on the demand side these range from bottom-up, end-use accounting techniques to top-down macroeconomic modelling. Most of its calculations occur on an annual time step which can extend for an unlimited number of years.

CHAPTER 3:SURVEY DESIGN AND DETERMINATION

3.1 Project Location

The project was conducted within the borders of the Kathmandu valley. The location was further divided into different clusters as per the requirement of the assignment. Similarly, the study was conducted for residential and commercial sectors. Kathmandu valley consists of the three districts namely Kathmandu, Bhaktapur and Lalitpur and has a population and households of 3,035,941 and 787,725 respectively[14]. Similarly, there are 104,664 food and accommodation entities as categorized by National Standard for Industrial Categorization (NSIC)[15]. The project location for the proposed location is shown in Figure 3.1.

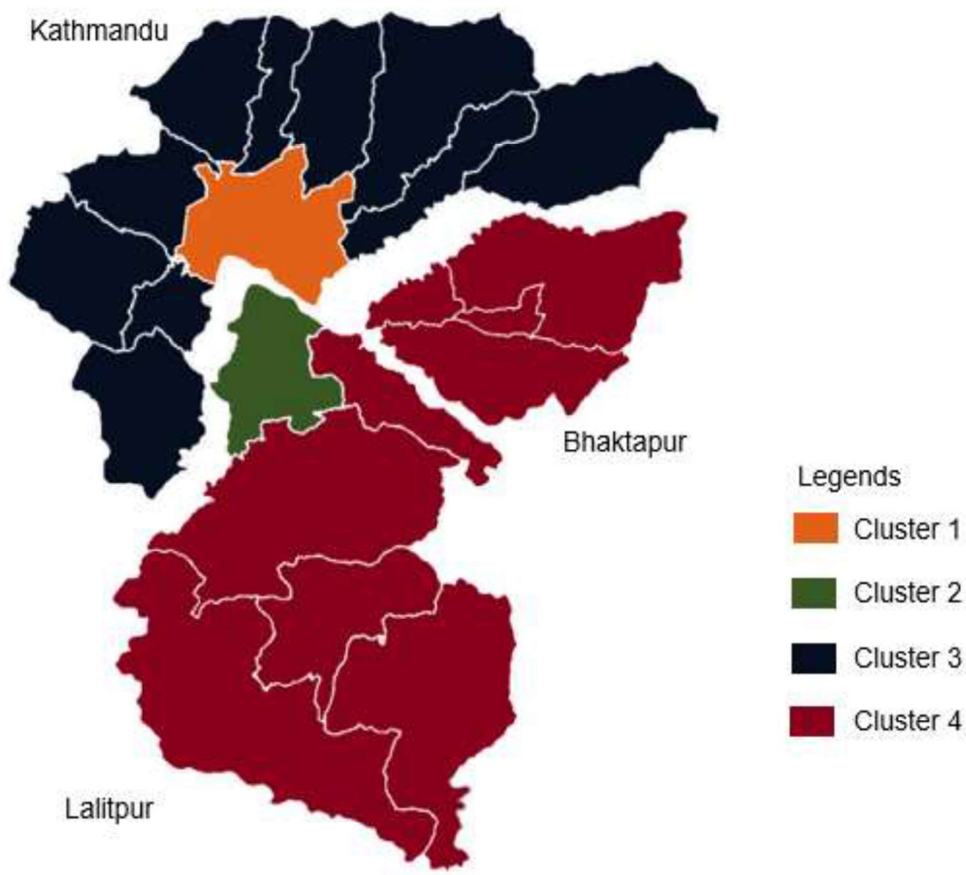


Figure 3.1: Survey location

In regards to the data collection, the project location was further been divided into four different clusters based on the local levels within the Kathmandu valley.

3.2 Questionnaire design

A comprehensive questionnaire was designed to gather information on the consumption and availability of different fuels and technologies used for cooking, as well as to assess the user's

[14] https://cbs.gov.np/wp-content/upLoads/2022/01/Final%20Preliminary%20Report%20of%20Census%202021%20Newfinal.pdf
[15] https://cbs.gov.np/national-eeconomic-census-2018-ward-profile-tables-data-in-pdf/

behaviour and challenges associated with transitioning to cleaner cooking methods. The detailed questionnaire can be found in Annex 2 of this report. The questionnaire has been developed by following a set of core questions developed by WHO with a close cooperation with World Bank and stakeholders. These guidelines included a breadth of topics, i.e., primary and secondary fuels and technologies used for cooking, cost and availability of fuel, time spent using devices, time spend collecting fuel, characteristics of cooking location, etc. To ensure accuracy and relevance, separate questionnaires were specifically tailored for the residential and commercial sectors. This approach allows for a thorough understanding of the specific dynamics and requirements unique to each sector. The questionnaire aims to capture valuable insights regarding the current cooking practices, preferences, and perceptions of users. It also seeks to identify the barriers and challenges faced by households and commercial entities when considering a shift towards cleaner and more sustainable cooking technologies. The questionnaire was used to collect following information as shown in Figure 3.2.

Figure 3.2: Contents in questionnaire

3.3 Sampling method

This study employs a comprehensive research approach, combining both quantitative and qualitative research methods to ensure a robust analysis. The primary focus of data collection has been on gathering information from primary sources, which involves direct interaction with household and commercial entities. Additionally, secondary sources, such as National and International reports on energy sectors, have been consulted to supplement the findings.

The sample size has been estimated based on the Krejci and Morgans sampling formula with 95% level of confidence, 5% margin error and at 5% non-response rate. During the data collection, the sample is taken in a manner that it represents the overall population.

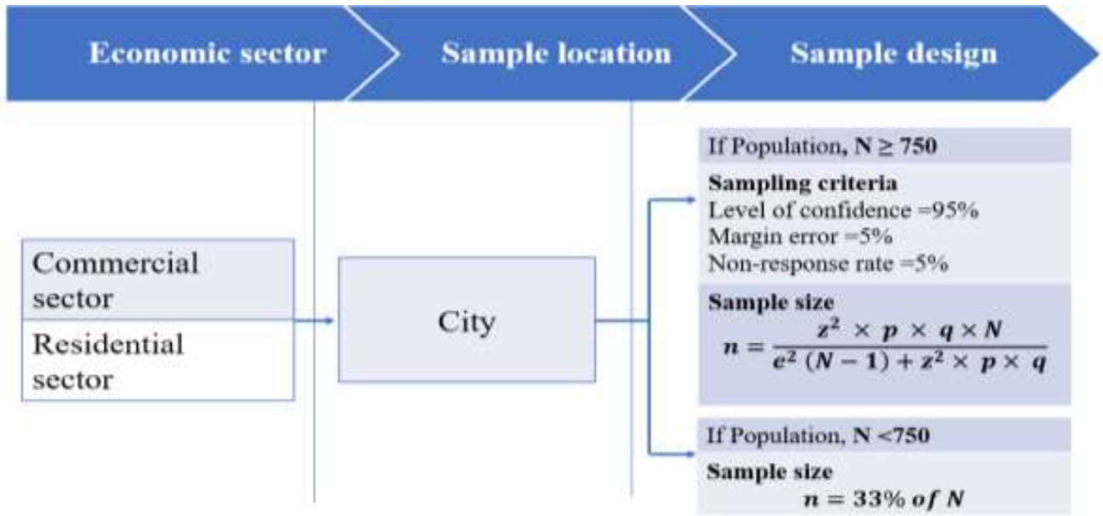


Figure 3.3: Sampling design

The detail of sampling is shown in Figure 3.3. The symbol represented denotes

- z^2 = Z 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

For 5% non-response rate the total sample size in each sector = $1.05 \times n$. The z^2 is a table value which depends on degree of freedom at a given confidence level.

3.3.1 Residential sector

In residential sector, household is taken as sample unit whereas four clusters are taken as the location for sampling. Sampling has been distributed proportionally on the basis of roof types on the basis of CBS classification. The population size, i.e., number of households for both cities is considered from preliminary report of census 2021. In regards to cluster one all the wards within the Kathmandu valley are covered while in regards to the cluster two all the wards within the Lalitpur Metropolitan City are covered. In regards to cluster 3 and cluster 4 all the municipality within the cluster are covered. The data collection is also done by considering different educational status of household, house occupancy status, major source of income, type of building, and types of roof of house. The detail of the sampling for residential sector of four clusters is shown in Table 3.1

3.3.2 Commercial sector

The population size of the commercial sector is considered from "National Economic CBS" published by CBS in 2018. The commercial sub sector is also sub categorized based on National Standard Industrial Classification (NSIC). Furthermore, the samples in the commercial sector are subcategorized as hotels, restaurant, hotels, hostels, canteen etc. The information about the building along with the information about the institution are also assessed. The detail of the sampling for commercial sector of four clusters is shown in Table 3.1

Table 3.1: Details of sample size

Residential sector		
Clusters	Total Households	Sampled Households
Cluster 1	231,714	403
Cluster 2	77,872	402
Cluster 3	306,202	403
Cluster 4	171,587	403
Total samples taken		**1611**
Commercial sector		
Clusters	Total Entities	Sampled Entities
Cluster 1	13,015	392
Cluster 2	2,856	356
Cluster 3	8,879	387
Cluster 4	4,898	375
Total samples taken		**1510**

3.4 Data collection and assurance

The paper based questionnaires developed served as the primary tool for conducting the survey and collecting relevant information. In the residential sector, the primary data collection involved conducting interviews with the head of each household. These interviews were conducted to ensure accurate and first-hand information regarding their cooking practices, fuel usage, preferences, challenges, and willingness to adopt new technologies. In the commercial sector, authorized representatives of the entities were interviewed to gather data on their cooking technologies, fuel preferences, consumption patterns, and barriers to adopting cleaner cooking practices. In addition to primary data collection, the study also utilized secondary data from various sources. Population size, growth rate, and other relevant demographic information were obtained from reputable ministries, governmental institutions, and associations.

A training program was organized for the team members including supervisors and enumerators before mobilization of the staffs. The training program helped to familiarize the field staff with the prepared questionnaire and ways of data collection along with clearing any queries among the field staff. To ensure the highest quality of data, a rigorous quality assurance process was implemented throughout the data collection phase. The following measures were taken to maintain the integrity and reliability of the collected data:

- The questionnaires were carefully designed by experts in the field, taking into account the research objectives and the specific information required. Feedback and suggestions from clients and stakeholders were incorporated to ensure the relevance and comprehensiveness of the questionnaires.
- Enumerators responsible for conducting the surveys underwent comprehensive training.
- The data collection process was continuously monitored to identify and address any potential issues or inconsistencies.
- Officials WECS were involved in monitoring the data collection activities during the survey phase.
- The core team responsible for the study provided ongoing feedback and guidelines to enumerators and supervisors. This feedback ensured that any issues or challenges encountered during data collection were promptly addressed.

CHAPTER 4: FINDINGS OF THE STUDY

4.1 Cooking in residential sector

Cooking technologies and fuels used in any household depends on numerous factors like cultural and regional influences, availability of energy sources, infrastructure requirements, and personal preferences. Additionally, environmental awareness and pollution concerns also influences the cooking methods adopted by various households.

4.1.1 Cooking technologies

In this study, the different types of cooking technologies used by various households were studied to identify the cooking practices of the households. Cooking technologies can vary in terms of their energy consumption. Some methods may require more energy than others, leading to increased environmental impact and higher energy costs. By studying cooking technologies, we can identify energy-efficient methods that reduce the environmental footprint associated with food preparation.

Based on the outcomes of the survey conducted, LPG cook stove is predominantly used in the residential areas of the Kathmandu valley. In the base year i.e., 2022, LPG stoves were used in 97.39% of the households followed by rice cooker at 25.09% of the households. In addition, the electric kettles are used in 11.80% of the households while electric stoves which includes induction stove and infrared stove is used in 10.19% of the households. Similarly, 13.42% of the households still employed traditional methods of cooking using the biomass-based cook stoves. The details of the cooking technology used in Kathmandu valley is presented in Figure 4.1.

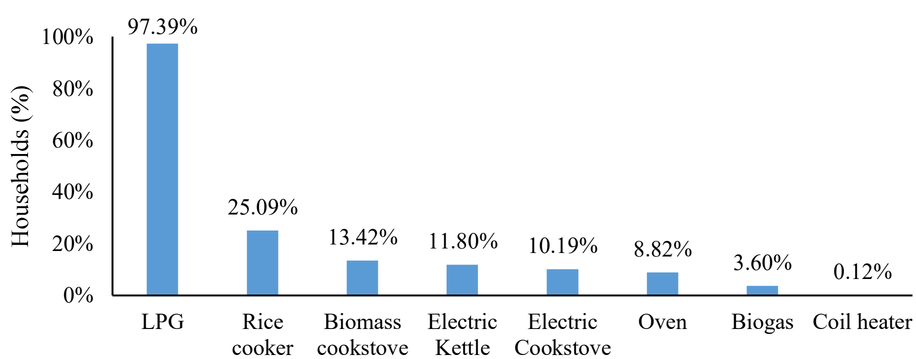


Figure 4.1: Cooking technologies used in residential sector of Kathmandu valley

4.1.2 Cooking fuels

The choice of cooking fuels is predominantly determined by the type of stoves used, although certain fuels can be utilized across multiple cooking technologies. For instance, electricity can power induction stoves, rice cookers, infrared stoves, coil heaters, and more.

Regarding the cooking fuels used in Kathmandu valley, LPG is used in 97.39% of the household while electricity is used in 43.54% of the households. Similarly, fuelwood is used in 13.48% of the households. The details of the cooking fuels used in Kathmandu valley is shown in Figure 4.2. The penetration of electricity as the cooking fuels whilst is encouraging, it should further be promoted to displace traditional fuels and imported fuels.

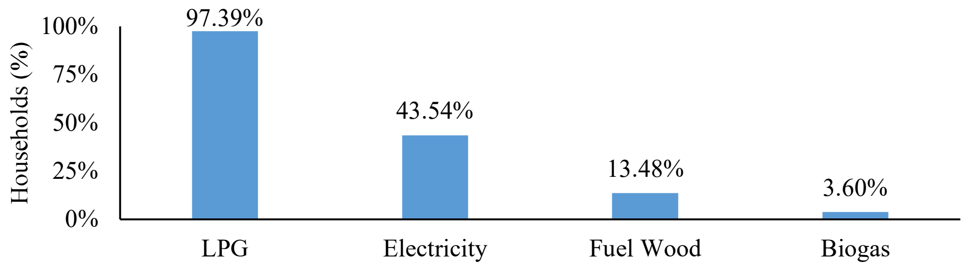


Figure 4.2: Cooking fuels in residential sector of Kathmandu valley

4.1.3 Stacking of technologies

The use of multiple stoves is called stove stacking. Using multiple stoves provides cooking flexibility, higher energy efficiency, and fulfils specialized cooking needs. The type of the stoves used by the households depends on a number of factors like availability, cost, energy efficiency, cultural practices, and need. By assessing the information about the type of stove stacking practiced by the households, we can identify the inefficient models that consume excessive amounts of fuel or electricity and promote energy efficient stoves to reduce energy consumption and lower greenhouse gas emissions.

From the survey, it is observed that about 47.79% households only one type of stove for cooking while the remaining 37.40% houses used two types of cooking technique, whereas the remaining 14.87% used more than two types. In most cases with two or more technologies, rice cooker is predominating second technology as 13.25% households use a combination of LPG and rice cooker for cooking. The Figure 4.3 indicates the various combination of cooking techniques employed by the households.

13.25% LPG + Rice cooker	7.16% LPG + Kettle	4.67% LPG + Induction	4.42% LPG + Oven	1.31% LPG + Induction + Rice cooker + Electric Kettle
6.35% Biomass based cookstove + LPG	0.31% Biomass based cookstove + Biogas	0.12% Biomass based cookstove + Rice Cooker	0.06% Biomass based cookstove + Oven	1.24% Biomass based cookstove + LPG + Rice cooker
3.42% LPG + Rice cooker + Oven	3.36% LPG + Rice cooker + Electric Kettle	0.12% Induction + Rice cooker + Oven	1.24% Biomass based cookstove + LPG + Biogas	0.50% Biomass based cookstove + LPG+ Rice Cooker + Electric Kettle

Figure 4.3: Stacking of cooking technologies in residential sector of Kathmandu valley[16]

4.1.4 Stacking of fuels

Regarding the fuels used for cooking, the type of fuel used varies from household to household and depends on the cooking technology employed in the household. It is important to study the

[16] (Primary+ Secondary+ Tertiary)

type of cooking fuel used by the households to determine their environmental impact, extent of health implications, and to assess the energy efficiency.

From the data obtained from the survey, around 45.62% of the households uses only LPG for cooking while 0.12% uses only electricity for cooking and 1.92% use only fuelwood for cooking. Similarly, 47.11% uses two types of fuels while 5.35% uses more than two types of fuels. The details of the fuel stacking is shown in Figure 4.4. Although stacking highlights multiple technology/ fuel used in the residential kitchens of the Kathmandu Valley, but the households prefer one mode of the cooking technologies/ fuels while uses rest as the secondary mode of cooking. Hence it is important to identify the primary mode of cooking in the different households.

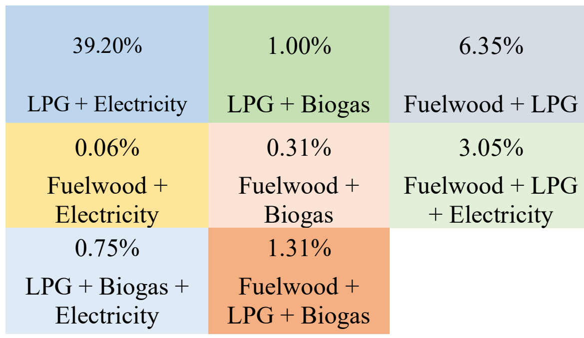


Figure 4.4: Stacking of cooking fuels in residential sectors of Kathmandu valley[17]

4.1.5 Energy consumption in cooking

The heat energy obtained from the combustion of various fuels is used for cooking. However, different factors like incomplete combustion of fuels, poor heat retention in cooking areas, and external environmental factors affect the efficiency of fire-based cooking technologies. Further, in electrical cooking equipment copper loss incurred due to coil heating during cooking causes its efficiency to drop. For the analysis, the efficiency of LPG and biomass-based fuel is considered to be 48% and 15% respectively. Further, since the efficiency of a cookstove is based on heat transfer only, and considering the losses, the efficiency of electricity as cooking fuels is taken as 90%. Further, the energy that is equivalent to the cooking fuel is known as final energy whereas the amount of energy actually used for cooking is known as useful energy. The total energy consumption of the residential sector of Kathmandu valley is shown in Table 4.1.

Table 4.1: Energy consumption in residential areas of Kathmandu valley

SN	Fuels Used	Final energy (TJ)	Average Efficiency	Useful energy (TJ)
1	Biogas	1.57	37%	0.58
2	Fuelwood	2151.47	15%	322.72
3	Electricity	486.63	90%	437.96
4	LPG	4096.29	48%	1966.21
Total		6735.96		2727.48
Population				3,017,030
Specific energy consumption (GJ/Capita)				2.23

17 (Primary+ Secondary+ Tertiary)

The total final energy consumed by the households is found to be 6735.96 TJ, with LPG accounting for the highest, i.e., 60.81% of the total energy consumption. In the residential sector, the total useful energy is observed to be 2727.48 TJ whereas the specific energy consumption per capita is obtained to be 2.23 GJ/capita. The comparison of final energy and useful energy is shown in the following Figure 4.5

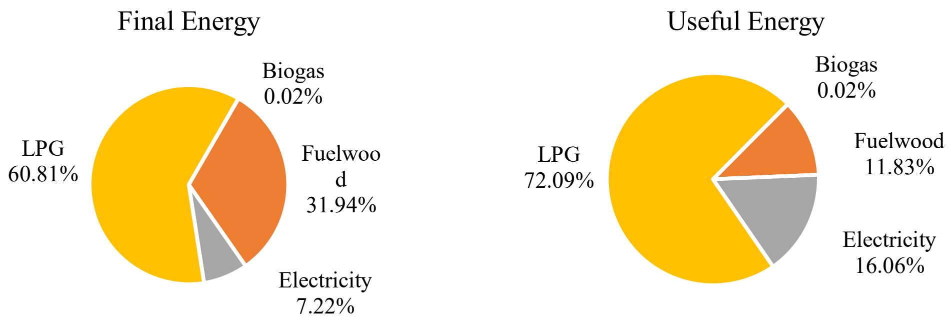


Figure 4.5: Comparison of final energy and useful energy of residential areas of Kathmandu valley

4.1.6 Type of kitchen and emission

It is important to access the information about the type of kitchen used by the households as it is one of the major factors which can affect the respiratory health of the users. Kitchens without proper exhaust systems can lead to the accumulation of harmful pollutants such as carbon monoxide, nitrogen dioxide, and particulate matter, which can adversely affect indoor air quality and potentially cause respiratory problems. By understanding the kitchen type, appropriate ventilation measures can be implemented to mitigate emissions, improve air quality, and safeguard the health and well-being of the household members. In Kathmandu valley, it was found that approximately 40.25% of households have indoor kitchens without proper exhaust systems and 2.92% practised cooking outdoor. The details of the type of kitchen used in four clusters is shown in Figure 4.6.

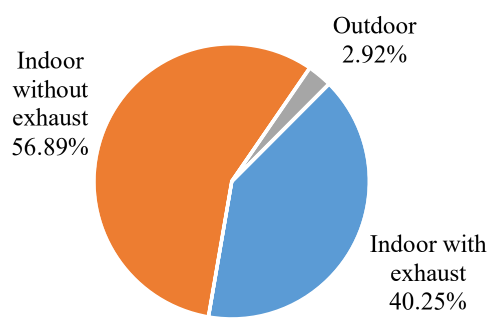


Figure 4.6: Types of kitchen used in Kathmandu Valley

4.1.6.1 GHG Emissions

The GHG emitted by the residential cooking sector of Kathmandu valley is shown in Table 4.2. Carbon dioxide is the major component of the GHG emission. The annual carbon dioxide emission is around 248 thousand tonnes from LPG stoves and 196 thousand tonnes from biomass-based stoves resulting in the total CO_2 emission of around 444 thousand metric tonnes.

Similarly, the total emission of methane has been found to be around 663.47 tonnes while that of Nitrous Oxide is 10.23 tonnes.

Table 4.2: GHG emissions from residential sector of Kathmandu valley

Fuel	Emission(tonnes)			
	CO_2	CH_4	N_2O	Total
LPG	248,554.03	11.68	2.50	248,568.21
Biomass based	195,794.15	651.79	7.73	196,453.67
Total	444,348.18	663.47	10.23	445,021.87

4.1.6.2 Local pollutant emissions

Besides the greenhouse gases, there is a presence of different local pollutants in the emission from the cooking fuels. The total Carbon Monoxide (CO) emission from the residential sector of Kathmandu valley is 8.9 thousand tonnes which is the highest among the local pollutants. The emissions of different local pollutants from the cooking processes of residential sector is shown in Table 4.3.

Table 4.3: Emission of local pollutants in residential sector of Kathmandu valley

Fuel	Local Pollutant Emissions (tonnes)								
	PM	SO_2	CO	NO_X	NH_3	C_{TNMVOC}	BC	OC	Total
LPG	21.69	27.52	310.28	146.80	-	133.45	16.68	4.17	660.59
Biomass based	492.06	1.03	8,913.79	154.57	166.17	559.04	38.64	218.98	10,544.29
Total	513.75	28.55	9,224.06	301.37	166.17	692.50	55.33	223.15	11,204.87

4.1.7 Cost of cooking technology

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 crucial for several reasons. Firstly, it allows policymakers and researchers to assess the affordability and accessibility of different cooking options for households, especially in low-income communities. Understanding the cost of cooking technologies helps identify potential barriers to adoption and devise strategies to make clean and efficient cooking solutions more affordable and available to a wider population. Secondly, cost information aids in evaluating the economic viability of transitioning from traditional and inefficient cooking methods, such as solid fuels or biomass, to cleaner and more sustainable alternatives like electric or clean cookstoves. 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. Ultimately, this information supports the development and implementation of effective policies and initiatives aimed at promoting sustainable and affordable cooking practices, improving health outcomes, and reducing environmental pollution. The detail of the cost of different technology is presented in Table 4.4

Table 4.4: Cost of cooking technologies in residential sector of Kathmandu Valley

SN	Fuel	Specific energy consumed		Specific cost of fuel	
		Unit	Quantity	Unit	Quantity
1	Fuelwood	kg/person/month	3.55	Nrs./person/month	53.22
2	LPG	kg/person/month	3.73	Nrs./person/month	473.28
3	Electricity	kWh/person/month	2.30	Nrs./person/month	20.68

In addition to the cost of fuel, the technology like LPG requires continuous maintenance. The cost of operating and maintenance based on the survey is shown in Table 4.5.

Table 4.5: Cost of operating and maintenance of LPG stoves

SN	Technology	Units	Cost involved with stove		
			Initial (NRs.)	O & M (NRs.)	Lifetime (Years)
1	LPG	Average	4750	1350	7
		Maximum	8,500	2500	12
		Minimum	1,000	200	2

4.1.8 Users perception

It is important to assess the user's perception towards their technology used for cooking to understand their level of awareness, behaviour and cultural barriers, user experience, and openness towards new technologies. The households were questioned about how using various technologies and fuels can result in accidents and health problems, take more time, and cost a lot of money. These perceptions were crucial since they informed whether people wanted to switch to more environmentally friendly technologies or not.

The

Figure 4.7 provides insights into the gender-based variations in user perceptions of cooking technologies. It is evident that significant differences exist between males and females in terms of their perceptions related to the cost of cooking. Approximately 61.40% of males consider their cooking technology expensive, while 48.33% of females share the same perception. Whereas, both genders exhibit similar perceptions regarding health issues, safety, and time efficiency associated with their cooking methods. These gender-based disparities in perception emphasize the need for targeted interventions and awareness campaigns to address safety concerns, improve health aspects, and promote time-efficient cooking technologies, considering the specific concerns and preferences of different genders.

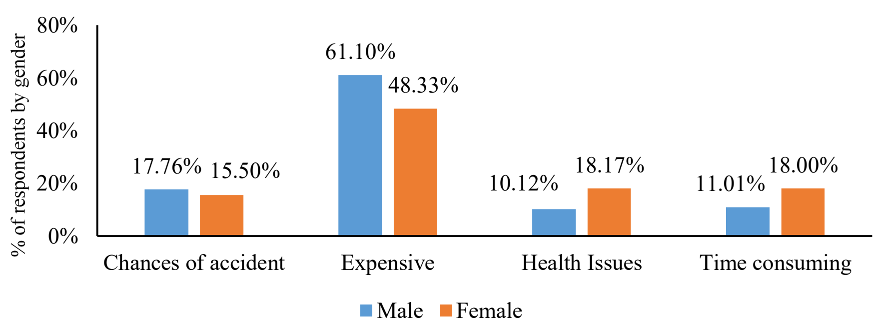


Figure 4.7: User perception in terms of gender

4.1.9 Willingness to use clean technology

The households were also asked about their interest in switching to other technologies as part of the study. In residential areas of Kathmandu valley, about 72.36% of the respondents showed willingness to switch to clean technologies. Understanding consumer willingness to switch to clean technologies is crucial for driving market transformation, achieving sustainability goals, unlocking economic opportunities, improving public health, and promoting behaviour change towards a cleaner and more sustainable future.

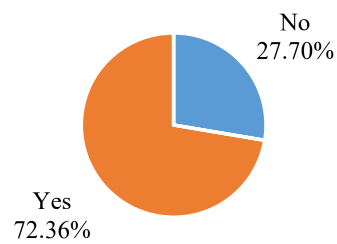


Figure 4.8: Consumer's willingness towards shifting technology

Among the respondents, all households preferred switching to electric cook stoves like induction or infrared stoves. There might be several reasons for such preference. First of all, electric cook stoves produce zero direct emissions during operation, unlike traditional cook stoves that rely on burning fossil fuels or biomass. By switching to electric cook stoves, individuals can significantly reduce their carbon footprint and contribute to mitigating climate change and air pollution. Further, electric cookstoves can be more energy-efficient compared to traditional cookstoves, especially if the electricity is generated from renewable sources. They can convert a higher proportion of the input energy into heat, resulting in less wasted energy.

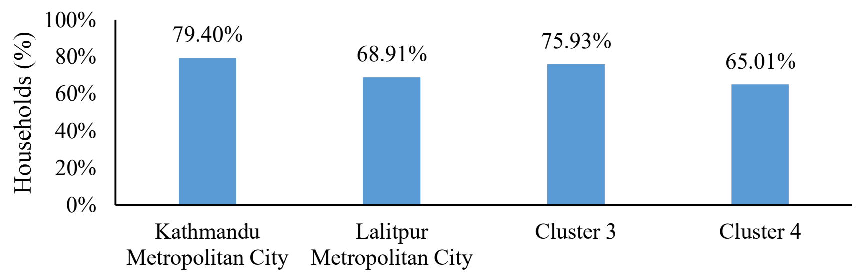


Figure 4.9: Percentage of households switching to electric cook stoves.

4.1.10 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 Kathmandu valley is shown in Figure 4.10. According to the survey, the majority of the respondents, i.e., 27.38% wanted to switch due to the better technologies available in the market. Further, 21.46% showed an interest for switching due to the lower cost of new technologies. Further, 13.82% of the respondents were willing to switch due to the chances of health hazard with current technologies.

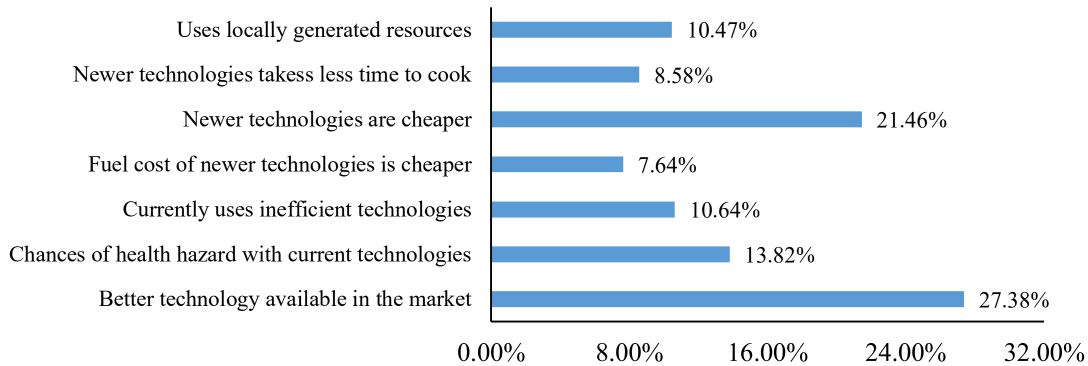


Figure 4.10: Reasons for shifting

Assessment of Shifting Trend

The household's intentions to switch to alternative technologies over the course of 15 years in five year's intervals were also studied. They were questioned about their preference for switching to only electricity, only LPG, and only electricity. As the majority of the people wanted to switch to clean technology, the shifting trend towards using electricity in the coming fifteen years shows an upward trend.

The trend of shifting in five years interval is shown in Figure 4.11. This shows that the percentage of population using only electricity for cooking in upcoming years would increase gradually and estimated to be 55.93% in 2037 while population using only LPG would gradually decrease till year 2037. In contrast, the population of using both LPG and electricity might increase till 2027 and after that year, it could get decreased.

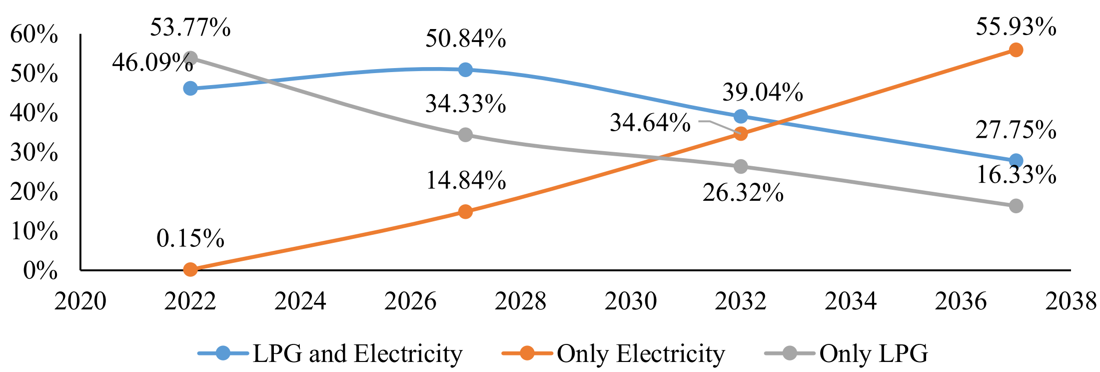


Figure 4.11: Shifting trend of residential sector of Kathmandu valley

4.1.11 Barrier identification

From the survey, we can observe that not every respondent were willing to switch to clean cooking technologies. Thus, it was crucial to understand the potential barriers that could have influenced their decision. The major barriers to shifting to electricity for cooking have been identified as follows:

- Electricity supply is not reliable: Clean cooking technologies, such as electric stoves or induction cooktops, require a reliable electricity supply to function. If the electricity supply is unreliable, with frequent power outages or fluctuations, it can disrupt the cooking process and make it inconvenient or impractical to rely on electric cooking appliances.

- Lack of information regarding other technologies: If individuals are not aware of the availability and benefits of clean cooking technologies, they may not consider 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.
- No other options available in market: The households generally have a set of utensils that they have been using as per the cooking technologies. The need for specific utensils can act as a barrier in switching to clean cooking technologies because individuals may already possess a set of traditional utensils that are not compatible with the new technologies. Thus, the households believe there are no other options available in market in terms of utility.
- New technologies are expensive: When switching to new technologies, the households have to bear upfront cost, fuel cost, and other operating cost associated with the cooking technologies. These costs when add up together might reduce the affordability of cooking technique.
- Food tastes better in current technology: The perception that food tastes better when cooked using current technology can act as a barrier in switching to clean cooking technologies. People may have a strong attachment to the flavors and textures produced by traditional cooking methods, such as open fire or gas stoves, which they believe enhance the taste of their food. The familiarity and cultural associations with these traditional flavors can make individuals hesitant to switch to cleaner cooking technologies, even if they offer environmental and health benefits.
- Uses the best technology available: The belief that people already use the best available technology can act as a barrier in switching to clean cooking technologies. Individuals may have a sense of satisfaction or contentment with their current cooking methods, believing that they are already utilizing the most effective and efficient technology. This perception can create resistance to change and a reluctance to explore alternative options, including cleaner cooking technologies.

The barriers have been classified as high, medium, and low priority. The distribution of respondents in terms of priority of Kathmandu valley is shown in Figure 4.12.

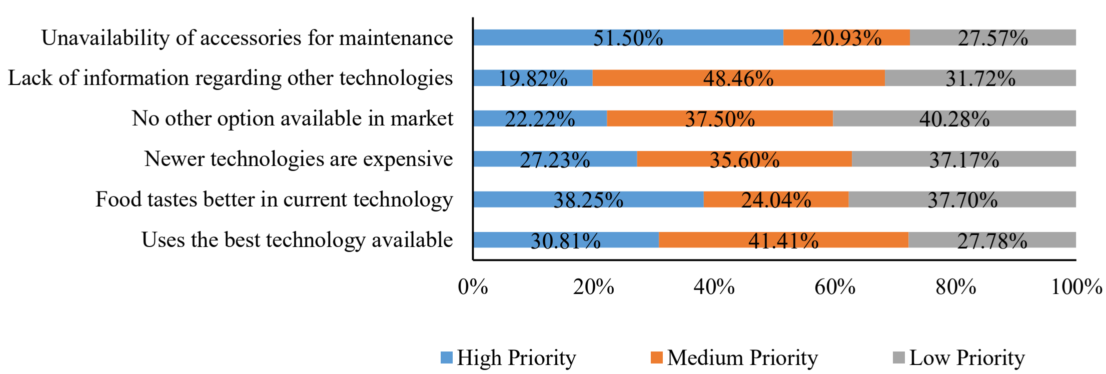


Figure 4.12: Barriers for shifting towards clean cooking technologies

According to the report, the residential sector as a whole is willing to switch over to electrical appliances. It is important to note that 19.88% of the sectors continue to use 6A fuses, while 63.79% use 16A fuses, which may not be sufficient for the proper operation of more recent electric technology. The fuse rating that users currently use could potentially act as a substantial barrier to switching to new technology given the growing trend of electric appliances.

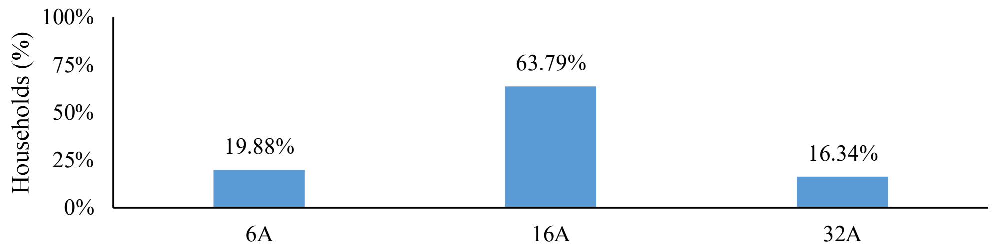


Figure 4.13: Fuse rating in Kathmandu valley according to survey

4.2 Cooking in commercial sectors

Due to the high per capita energy consumption, the cooking sector utilizes those cooking techniques which are more convenient, easy to use, and efficient than those used in the residential sector. LPG is the most common cooking fuel that is used in this sector. In addition, some of the users are also using electricity and biomass-based techniques for cooking. The users consider LPG stoves as the most convenient cooking technique and are positive towards the potential utilization of electricity-based cooking techniques due to their reliability and lower operating costs.

4.2.1 Cooking technologies

In this study, the different types of cooking technologies used by various entities were studied to identify the cooking practices of the entities. Cooking technologies can vary in terms of their energy consumption. Some methods may require more energy than others, leading to increased environmental impact and higher energy costs. By studying cooking technologies, we can identify energy-efficient methods that reduce the environmental footprint associated with food preparation.

Based on the outcomes of the survey conducted, LPG cook stove is predominantly used in the commercial areas of the Kathmandu valley. In the base year i.e., 2022, LPG stoves were used in 96.03% of the entities followed by electric cook stoves which includes induction stove and infrared stove at 14.04%. In addition, the rice cookers are used in 11.66% of the entities while electric kettles are used by 10.86% of the entities. Similarly, 6.62% of the entities still employed traditional methods of cooking using the biomass-based cook stoves. The details of the cooking technology used is presented in Figure 4.14.

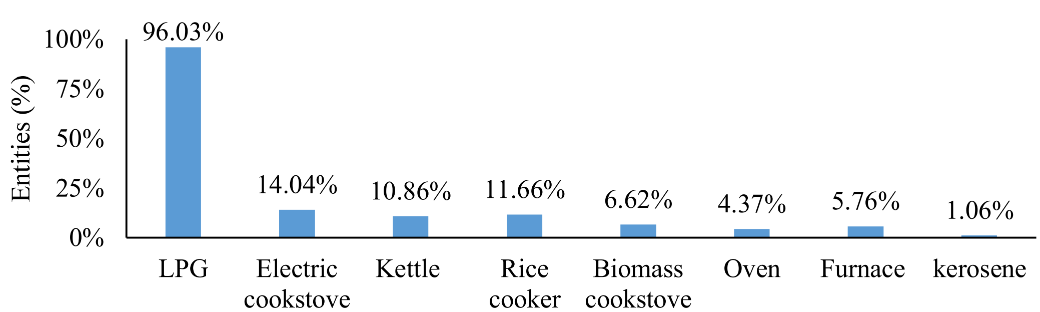


Figure 4.14: Cooking technologies used in commercial sector of Kathmandu valley

4.2.2 Cooking fuels

The choice of cooking fuels is predominantly determined by the type of stoves used, although certain fuels can be utilized across multiple cooking technologies. For instance, electricity can power induction stoves, rice cookers, infrared stoves, coil heaters, and more. Regarding cooking fuels, LPG is used in 96.03% of the entities while electricity is used in 35.17% of the entities. Similarly, coal and fuelwood is used in 5.76% and 6.62% of the entities respectively. The details of the cooking fuels used in Kathmandu valley is shown in

Figure 4.15. The penetration of electricity as the cooking fuels whilst is encouraging, it should further be promoted to displace traditional fuels and imported fuels.

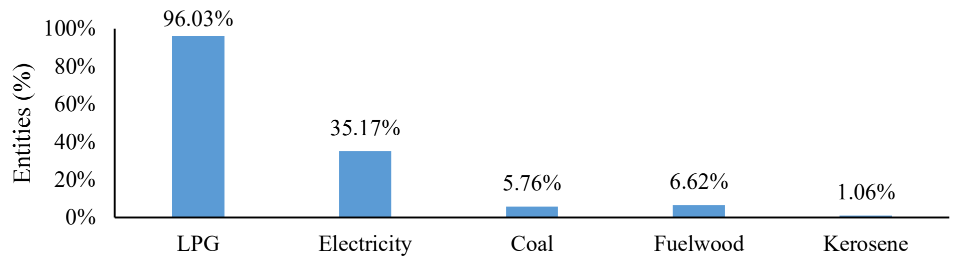
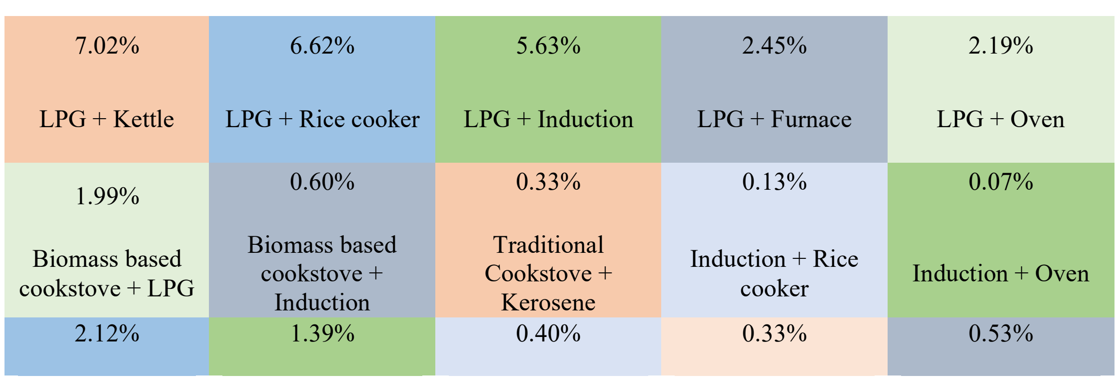


Figure 4.15: Cooking fuels in commercial areas of Kathmandu valley

4.2.3 Stacking of cooking technologies

The use of multiple stoves is called stove stacking. Using multiple stoves provides cooking flexibility, higher energy efficiency, and fulfils specialized cooking needs. The type of the stoves used by the entities depends on a number of factors like availability, cost, energy efficiency, cultural practices, and need. By assessing the information about the type of stove stacking practiced by the entities, we can identify the inefficient models that consume excessive amounts of fuel or electricity and promote energy efficient stoves to reduce energy consumption and lower greenhouse gas emissions.

For Kathmandu valley, from the survey, 62.25% of the sectors use a single type of stove for cooking, 27.22 % of the sectors utilize exactly two cooking techniques and 10.53% utilizes more than two. Among the cooking technologies used, LPG and kettle cover the highest share, i.e.,7.02%. Further, users are also utilizing biomass-based stoves with LPG or induction, which indicates that they are willing to use more efficient and clean cooking techniques. The Figure 4.16 indicates the various combination of cooking techniques employed by the entities.



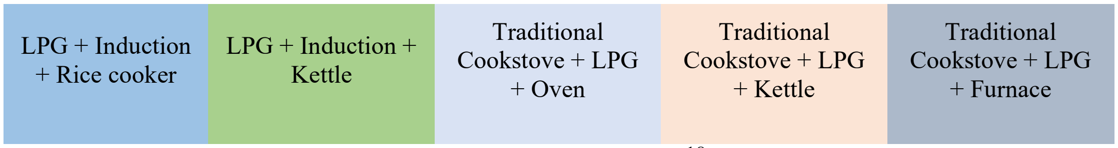


Figure 4.16: Stacking of cooking techniques[18] in Kathmandu valley

4.2.4 Stacking of cooking fuels

Regarding the fuels used for cooking, the type of fuel used varies between entities and depends on the cooking technology employed. It is important to study the type of cooking fuel used by the entities to determine their environmental impact, extent of health implications, and to assess the energy efficiency.

In Kathmandu valley, 60.07% of the entities use one type of fuel, 35.56% uses both, while 4.37% of the entities more than two types of fuels respectively. Among the entities using multiple cooking technologies, the combination of LPG and electricity emerged as the most prevalent, accounting for 29.21 % of such cases. Additionally, a small fraction of households, 2.65%, utilized a combination of LPG and coal for cooking purposes. The detail of the combination of these household is presented in Figure 4.17.

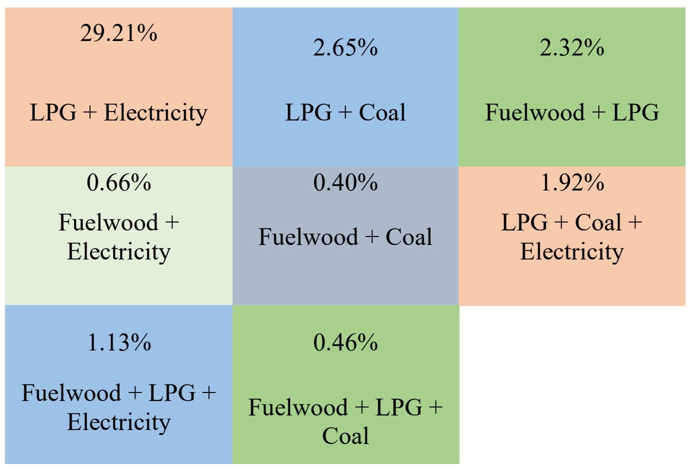


Figure 4.17: Fuel stacking in commercial sector of Kathmandu valley

4.2.5 Energy consumption in cooking

The heat energy obtained from the combustion of various fuels is used for cooking. However, different factors like incomplete combustion of fuels, poor heat retention in cooking areas, and external environmental factors affect the efficiency of fire-based cooking technologies. Further, in electrical cooking equipment copper loss incurred due to coil heating during cooking causes its efficiency to drop. For the analysis, the efficiency of LPG and biomass-based fuel is considered to be 48% and 15% respectively. Further, since the efficiency of a cookstove is based on heat transfer only, and considering the losses, the efficiency of electricity as cooking fuels is taken as 90%. Further, the energy that is equivalent to the cooking fuel is known as final energy whereas the amount of energy actually used for cooking is known as useful energy. The total energy consumption of the commercial sector of Kathmandu valley is shown in the Table 4.6.

[18] (Primary+ Secondary+ Tertiary)

Table 4.6: Energy consumption in commercial sector of Kathmandu valley

S.N.	Fuel Type	Final energy (TJ)	Efficiency	Useful energy (TJ)
1	Fuelwood	14.36	15%	2.15
2	LPG	2760.16	48%	1324.88
3	Coal	380.38	35%	133.13
4	Electricity	39.43	90%	35.49
Total Final energy (TJ)		3,194.33		1,495.65
Population				29,648
Specific energy consumption (GJ/entities)				107.74

The total final energy consumption amounts to 3194.33 TJ with LPG accounting for 86.41%. Moreover, the useful energy consumption of the sector is obtained to be 1495.65 TJ, resulting in a specific useful energy consumption of 107.74 GJ/entities. The comparison of final and useful energy is shown in Figure 4.18

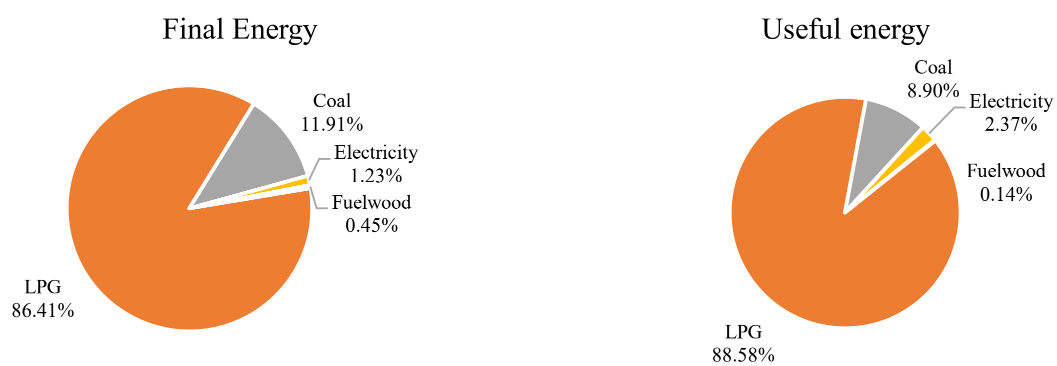


Figure 4.18: Comparison of final and useful energy

4.2.6 Type of kitchen and emission

It is important to access the information about the type of kitchen used by the entities as it is one of the major factors which can affect the respiratory health of the users. The type of kitchen used in the commercial entities might help to maintain air quality and prevent the buildup of harmful pollutants, such as grease, smoke, and odors. Proper ventilation helps create a safe and comfortable working environment for employees while ensuring the quality and hygiene of the food being prepared. According to the survey, about 65.17% of the entities practise indoor cooking with exhaust while 2.85% of the entities practise cooking outside. The details of type of kitchen used in four clusters is shown in Figure 4.19.

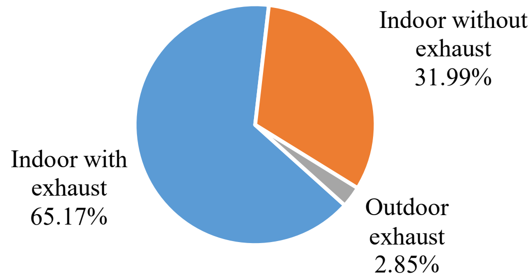


Figure 4.19: Types of kitchen used in commercial areas

4.2.6.1 GHG Emissions

The GHG emitted by the commercial cooking sector of Kathmandu valley is shown in Table 4.7. Carbon dioxide is the major component of the GHG emission. The annual carbon dioxide emission is around 85 thousand tonnes from LPG stoves and 983 tonnes from biomass-based stoves resulting in the total CO_2 emission of around 107 thousand metric tonnes. Similarly, the total emission of methane has been found to be around 34 metric tonnes while that of Nitrous Oxide is 0.9 metric tonne.

Table 4.7: GHG emission from the commercial sector

Fuel	Emission(tonnes)			
	CO_2	CH_4	N_2O	Total
LPG	167,257.04	7.86	1.68	167,266.58
Biomass based	1,297.67	4.32	0.05	1,302.04
Coal	31,674.70	84.67	0.00	31,759.37
Total	200,229.42	96.84	1.74	200,328.00

4.2.6.2 Local pollutant emissions

Besides the greenhouse gases, there is a presence of different local pollutants in the emission from the cooking fuels. The total Carbon Monoxide (CO) emission from the residential sector of Kathmandu valley is 805 metric tonnes which is the highest among the local pollutants. The emissions of different local pollutants from the cooking processes of commercial sector of Kathmandu valley is shown in Table 4.8.

Table 4.8: Emission of Local pollutants in commercial

Fuel	Emission(tonnes)								
	PM	SO_2	CO	NO_x	NH_3	C_{TNMVOC}	BC	OC	Total
LPG	14.59	18.52	208.79	98.78	0.00	89.80	11.23	2.81	444.52
Biomass based	3.26	0.01	59.08	1.02	1.10	3.71	0.26	1.45	69.88
Coal	18.06	37.09	990.53	12.70	0.00	9.22	10.56	5.56	1083.72
Total	35.91	55.62	1258.40	112.50	1.10	102.73	22.04	9.81	1598.13

4.2.7 Cost of cooking technologies

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 commercial sector is vital for several reasons. Firstly, it allows businesses and policymakers to assess the economic feasibility and potential return on investment of different cooking options in commercial settings, such as restaurants, hotels, and food establishments. Understanding the cost of cooking technologies helps identify cost-effective solutions that align with the budgetary constraints of commercial enterprises, encouraging the adoption of energy-efficient and sustainable cooking methods. Secondly, cost information aids in evaluating the financial benefits and potential savings associated with transitioning to cleaner and more efficient cooking technologies. This knowledge enables businesses to make informed decisions, reduce operational costs, and enhance their environmental performance. Additionally, understanding the cost of cooking technologies in the commercial sector facilitates the development of policies and incentives that promote the adoption of energy-efficient cooking practices, contributing to overall sustainability goals and reducing the environmental impact of commercial operations. The detail of the average cost of four clusters of different technology is presented in Table 4.9.

Table 4.9: Cost of cooking technologies in commercial sector of Kathmandu Valley

SN	Fuel	Specific energy consumed		Specific cost of fuel	
		Unit	Quantity	Unit	Quantity
1	Fuelwood	kg/person/month	2.41	Nrs./person/month	36.15
2	LPG	kg/person/month	30.79	Nrs./person/month	3902.38
3	Electricity	kWh/person/month	157.56	Nrs./person/month	1418.02

In addition to the cost of fuel, the technology like LPG requires continuous maintenance. The cost of operating and maintenance based on the survey is shown in Table 4.10.

Table 4.10: Cost of operating and maintenance of LPG stoves

SN	Technology	Units	Cost involved with stove		
			Initial (NRs.)	O & M (NRs.)	Lifetime (Years)
1	LPG	Average	8550	2150	8.5
		Maximum	14,500	4000	16
		Minimum	2,600	300	1

4.2.8 User's perception

It is important to assess the user's perception towards their technology used for cooking to understand their level of awareness, behaviour and cultural barriers, user experience, and openness towards new technologies. The entities were questioned about how using various technologies and fuels can result in accidents and health problems, take more time, and cost a lot of money. These perceptions were crucial since they informed whether people wanted to switch to more environmentally friendly technologies or not.

The Figure 4.20 offers valuable insights into the user perception of cooking technologies with respect to gender. Notably, approximately 22.19% of female participants and 25.20% of male participants perceive their cooking technology as time-consuming. While both genders express some degree of concern regarding the time spent on cooking, the data suggests a slightly higher proportion of males perceiving it as such. Further, the perception of the male and female respondents regarding cost, safety, and space efficiency of their cooking methods were similar.

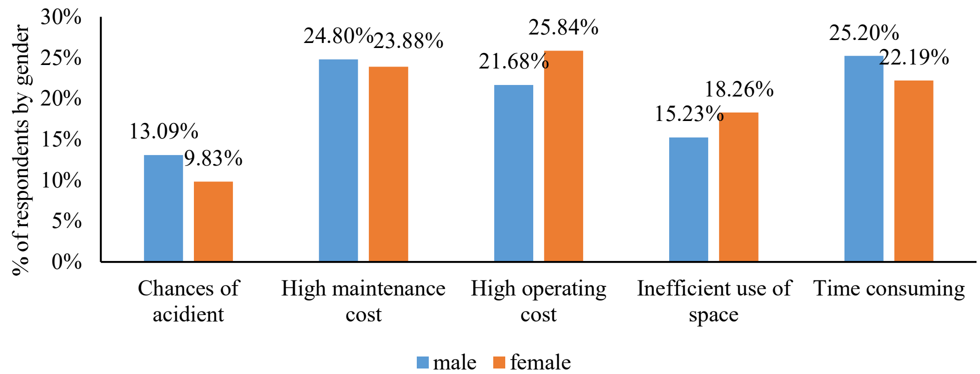


Figure 4.20: User Perception in terms of gender

4.2.9 Willingness to use clean technologies

The households were also asked about their interest in switching to other technologies as part of the study. In commercial areas of Kathmandu valley, about 57.48% of the respondents showed willingness to switch to clean technologies. Understanding consumer willingness to switch to clean technologies is crucial for driving market transformation, achieving sustainability goals, unlocking economic opportunities, improving public health, and promoting behaviour change towards a cleaner and more sustainable future.

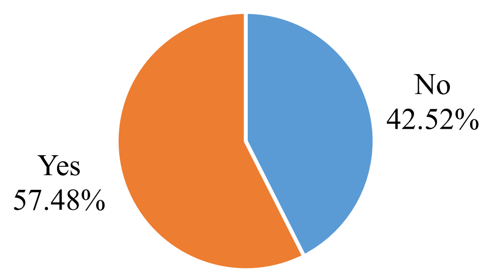


Figure 4.21: Consumer's willingness towards shifting technology

4.2.10 Reason for shifting

Various factors, such as technological advancements, economic considerations, health concerns, and socio-cultural influences, impact the willingness of the entities 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 is shown in Figure 4.22. According to the survey, the majority of the respondents, i.e., 25.23% wanted to switch due to the lower cost of new technologies. Further, 17.74% of the respondents were willing to switch due to the better technologies available in the market.

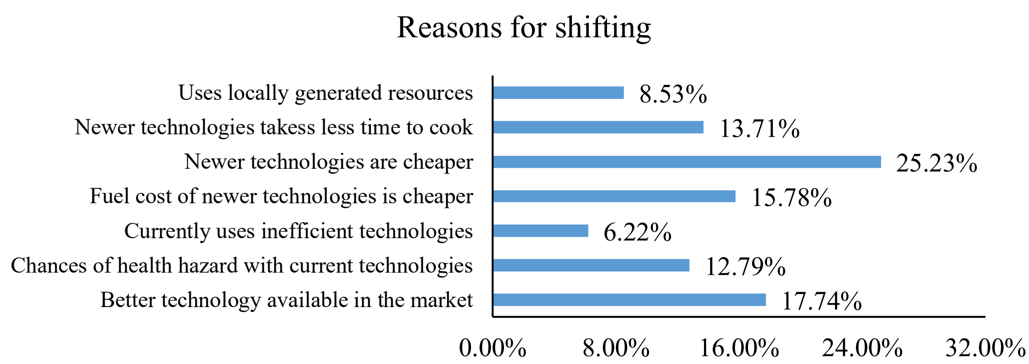


Figure 4.22: Reasons for shifting of commercial areas of Kathmandu valley

4.2.11 Barrier identification

From the survey, we can observe that not every respondent was willing to switch to clean cooking technologies. Thus, it was crucial to understand the potential barriers that could have influenced their decision. The major barriers to shifting to electricity for cooking have been identified as follows:

- Electricity supply is not reliable: Clean cooking technologies, such as electric stoves or induction cooktops, require a reliable electricity supply to function. If the electricity supply is unreliable, with frequent power outages or fluctuations, it can disrupt the cooking process and make it inconvenient or impractical to rely on electric cooking appliances.
- Lack of information regarding other technologies: If individuals are not aware of the availability and benefits of clean cooking technologies, they may not consider 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.
- No other options available in market: The entities generally have a set of large utensils that they have been using as per the cooking technologies. The need for specific utensils can act as a barrier in switching to clean cooking technologies because not all utensils can be feasible with electric cook stoves Thus, the entities believe there are no other options available in market in terms of utility.
- New technologies are expensive: When switching to new technologies, the entities have to bear upfront cost, fuel cost, and other operating cost associated with the cooking technologies. These costs when add up together might reduce the affordability of cooking technique. Since, the entities have to prepare food for a large number of people, adding new technologies can become quite expensive.
- Food tastes better in current technology: The perception that food tastes better when cooked using current technology can act as a barrier in switching to clean cooking technologies. People may have a strong attachment to the flavors and textures produced by traditional cooking methods, such as open fire or gas stoves, which they believe enhance the taste of their food. The familiarity and cultural associations with these traditional flavors can make individuals hesitant to switch to cleaner cooking technologies, even if they offer environmental and health benefits.
- Uses the best technology available: The belief that people are already using the best technology available can hinder the adoption of clean cooking technologies. People may feel satisfied with their current cooking methods, thinking they are already

using the most effective technology. This perception creates resistance to change and a reluctance to consider cleaner cooking alternatives.

The barriers have been classified as high, medium, and low priority. The distribution of respondents in terms of priority of Kathmandu valley is shown in Figure 4.23

Figure 4.23: Barriers for shifting in commercial sector

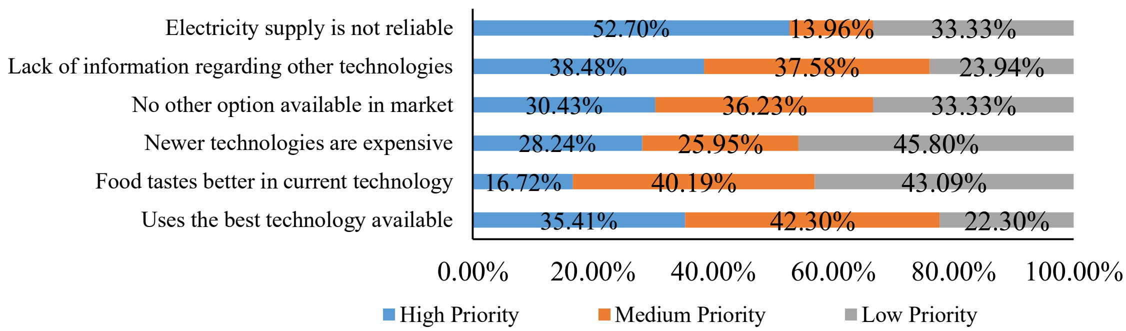


Figure 4.23: Barriers for shifting in commercial sector

According to the study, the commercial sector as a whole is willing to switch over to electrical appliances. In Kathmandu valley, it is important to note that 3.51% of the sectors continue to use 6A fuses, while 39.40% use 16A fuses, which may not be sufficient for the proper operation of more recent electric technology. The fuse rating that users currently use could potentially act as a substantial barrier to switching to new technology given the growing trend of electric appliances.

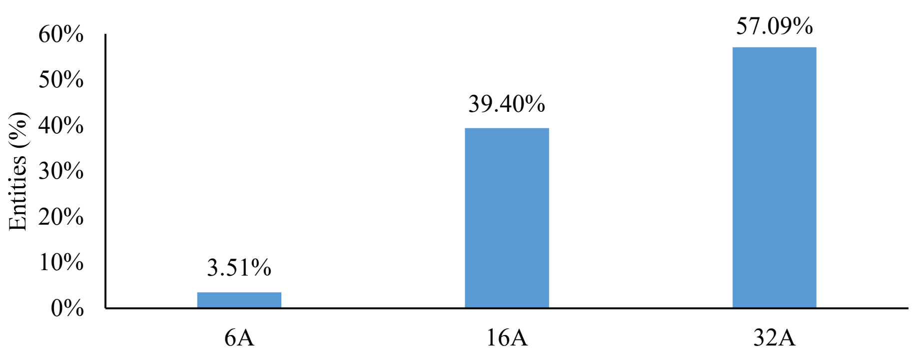


Figure 4.24: Fuse rating in commercial sector of Kathmandu valley according to survey

CHAPTER 5: ENERGY DEMAND FORECASTING

5.1 Modelling Methodology

The energy project was done using MAED (Model for Analysis of Energy Demand). The base year considered for the energy demand projection is 2022 and the energy was forecasted up to 2045. For the base year, the energy model was developed based on the data collected and analysed from the survey. The demographic data which includes population, population growth rate, and living areas, and the GDP and GDP growth rates were used. The penetration of useful energy of different fuels is entered and the final energy demand is forecasted. To forecast the energy demand of cooking sectors of the four clusters two scenarios has been considered namely business as usual and shifting scenario. To determine the energy demand, various assumptions were developed. In order to determine the energy consumption of different fuels, energy intensity i.e., specific energy consumption was used. The annual growth rate of the households is considered according to the UNDP index. As the major basis of energy calculation is cooking, the growth rate for food and accommodation in the commercial sector is considered the same as that of the residential sector.

5.2 Business as usual

In this scenario, the trend of cooking fuels is assumed to be the same for the upcoming years, i.e., the penetration of fuels is the same. The penetration of different fuels in final energy and useful energy is shown in Table 5.1.

Table 5.1:Penetration of different fuels under BAU scenario

S.N.	Fuel	Penetration of fuels in % (2023)	
		Final energy	Useful energy
Residential sector			
1	Traditional fuels	31.94%	11.83%
2	Biogas	0.02%	0.02%
3	Electricity	7.22%	16.06%
4	Fossil fuels	60.81%	72.09%
Commercial Sector			
1	Fuelwood	0.45%	0.14%
2	Electricity	1.23%	2.37%
3	LPG	86.41%	88.58%
4	Coal	11.91%	8.90%

Based on the assumptions made in this scenario, for cooking in residential sector, the energy consumption is forecasted to increase from 6735.97TJ in 2023 to 8617.48 TJ in 2045. The share of different fuels used for cooking in final energy demand for residential sector is shown in Table 5.2.

Table 5.2: Projection of energy demand for residential sector of Kathmandu valley

SN	Fuel	Energy Demand (TJ)					
		2023	2025	2030	2035	2040	2045
1	Traditional fuels	2151.47	2223.24	2379.769	2526.028	2653.566	2754.576
2	Biogas	1.57	1.565	1.673	1.783	1.87	1.94
3	Electricity	486.63	485.617	519.248	552.972	586.013	617.615
4	Fossil fuels	4096.29	4231.958	4529.903	4808.295	5051.072	5243.35

Total	6,735.97	6942.39	7430.592	7889.078	8292.51	8617.48

Similarly, in case of commercial sector, the energy demand for cooking is forecasted to become 4078.62 TJ in 2045 from 3193.72 TJ in 2023. The share of different fuels used for cooking in final energy demand for commercial sector is shown in Table 5.3.

Table 5.3: Projection of energy demand for commercial sector of Kathmandu valley

SN	Fuels	Energy Demand (TJ)					
		2023	2025	2030	2035	2040	2045
1	Traditional fuels	14.36	14.733	15.765	16.734	17.587	18.265
2	Coal	380.46	392.537	420.171	445.997	468.517	486.347
3	Electricity	37.82	36.861	39.461	41.884	43.996	45.658
4	Fossil fuels	2760.34	2847.76	3048.25	3235.58	3398.95	3528.34
	Total	3193.72	3291.9	3523.66	3740.21	3929.05	4078.62

5.3 Shifting scenario

The shifting scenario has been developed by changing the penetration of different fuels. The energy demand forecast in this scenario is done on the basis of target of Nepal's Long-term Strategy for Net Zero Emission plan. The share of electricity is assumed to be 100% at 2045 and hence the increasing or decreasing trend of share of other fuels are adjusted by using the assumption. Based on the above-mentioned assumption the penetration of different fuels in useful energy is shown in Table 5.4.

Table 5.4: Penetration of different fuels under shifting scenario

SN	Fuel	Penetration of fuels (%)					
Residential							
		2023	2025	2030	2035	2040	2045
1	LPG	72.09%	58.67%	42.95%	27.27%	11.63%	0%
2	Biomass based	11.83%	11.06%	8.48%	5.91%	3.34%	0%
3	Electricity	16.06%	27.29%	45.59%	63.85%	82.06%	100%
4	Biogas	0.02%	0.09%	0%	0%	0%	0%
Commercial							
		2023	2025	2030	2035	2040	2045
1	LPG	88.58%	74.44%	55.12%	35.86%	16.64%	0%
2	Biomass based	0.14%	0.05%	0%	0%	0%	0%
3	Electricity	2.37%	14.65%	35.94%	57.17%	78.35%	100%
4	Coal	8.90%	7.61%	5.67%	3.74%	1.81%	0%

Based on the assumptions made in this scenario, for cooking in residential sector of Kathmandu valley, the energy consumption is forecasted to change from 6735.90 TJ in 2023 to 3486.42 TJ in 2045. The share of different fuels used for cooking in final energy demand for residential sector is shown in Table 5.5.

Table 5.5: Projection of energy demand for residential sector of Kathmandu valley

SN	Fuel	Energy Demand (TJ)					
		2023	2025	2030	2035	2040	2045
1	Traditional fuels	2151.47	1873.343	1463.313	980.727	429.56	0

2	Biogas	1.57	0.421	0	0	0	0
3	Electricity	486.63	674.768	1298.889	1989.088	2729.31	3486.42
4	Fossil fuels	4096.29	3870.841	3111.769	2210.332	1176.71	0
Total		6735.97	6419.381	5873.972	5180.156	4335.60	3486.42

Similarly, in case of commercial sector, the energy demand for cooking is forecasted to become 1911.42 in 2045 from 3193.72 in 2023. The share of different fuels used for cooking in final energy demand for commercial sector is shown in Table 5.6.

Table 5.6: Projection of energy demand for commercial sector of Kathmandu valley

SN	Fuels	Energy Demand (TJ)					
		2023	2025	2030	2035	2040	2045
1	Traditional fuels	14.36	10.171	5.22	0	0	0
2	Coal	380.46	296.118	260.188	174.577	79.947	0
3	Electricity	37.82	171.479	551.056	974.017	1263.781	1911.42
4	Fossil fuels	2760.34	2630.466	2093.584	1487.554	790.523	0
	Total	3193.72	3121.017	2925.384	2654.988	2317.65	1911.42

5.4 Comparative analysis

5.4.1 Residential sector

Figure 5.1 shows the energy demand in Business as Usual (BAU) and shifting scenarios. This shows that the demand of energy decreases in shifting scenario than in the BAU scenario as the use of more efficient technology is done in shifting scenario. The total energy demand in year 2045 would be 8.62 PJ and 3.49 PJ in BAU scenario and shifting scenario respectively.

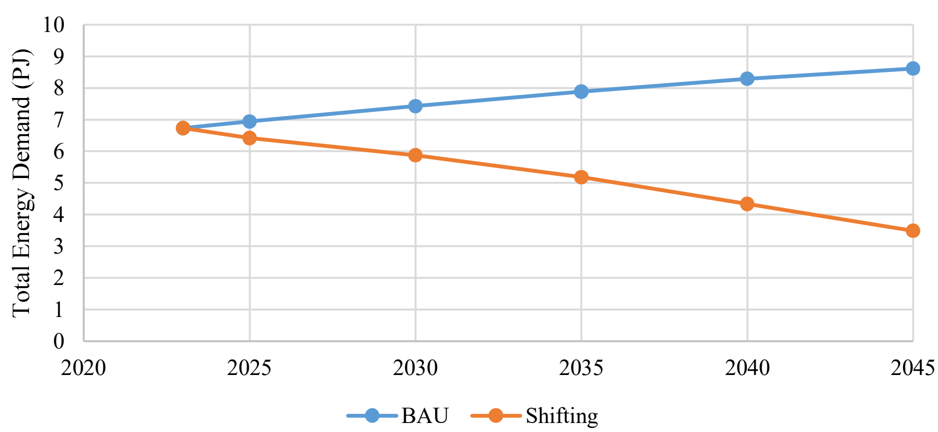


Figure 5.1: Total final energy demand in residential sector

The Figure 5.2 shows the fuel wise comparison of the energy demand in BAU and shifting scenarios.

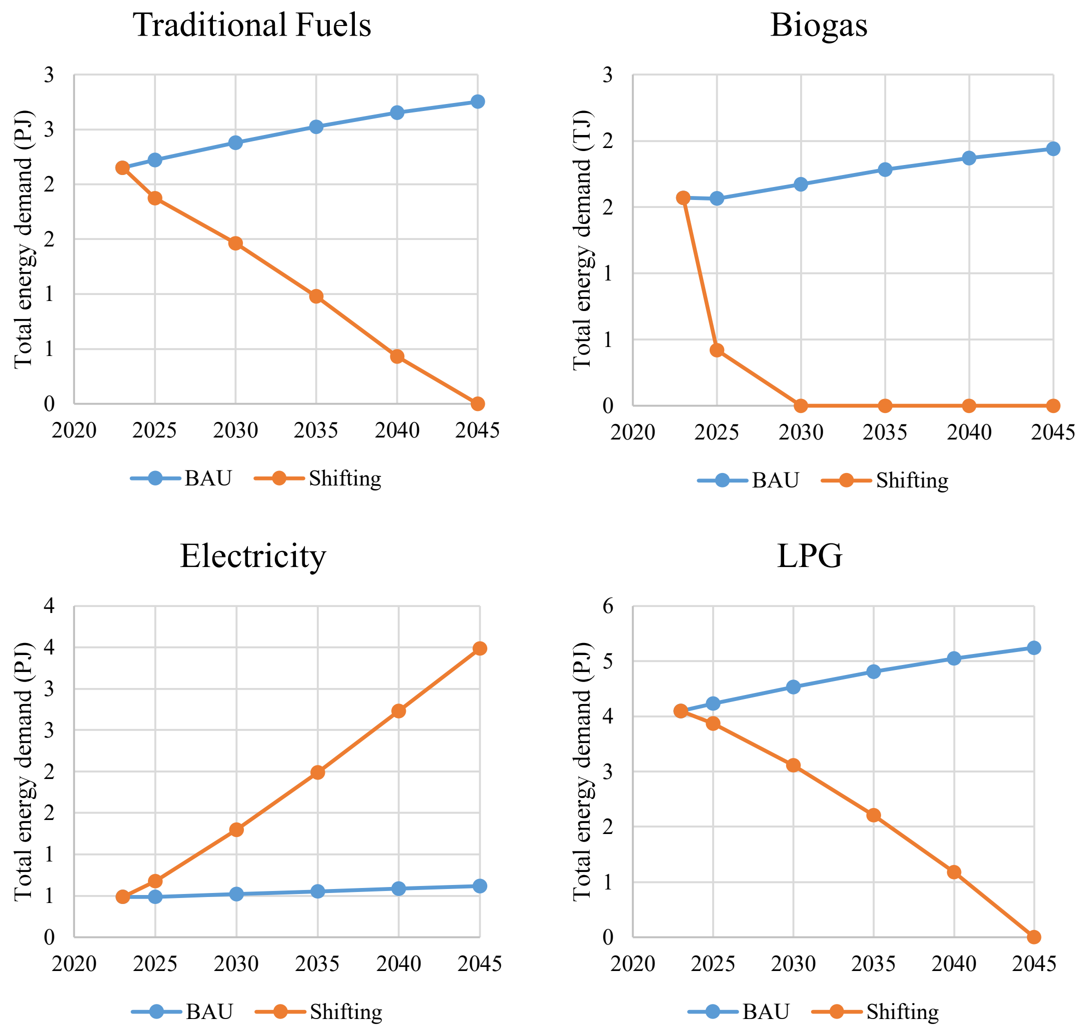


Figure 5.2: Fuel wise comparison

Figure 5.3 shows the GHG emission in residential sector of Kathmandu valley for the BAU and shifting scenario. The production of GHG gas would be in decreasing order in shifting scenarios as the use of fossil fuels and traditional biomass is replaced by clean energy.

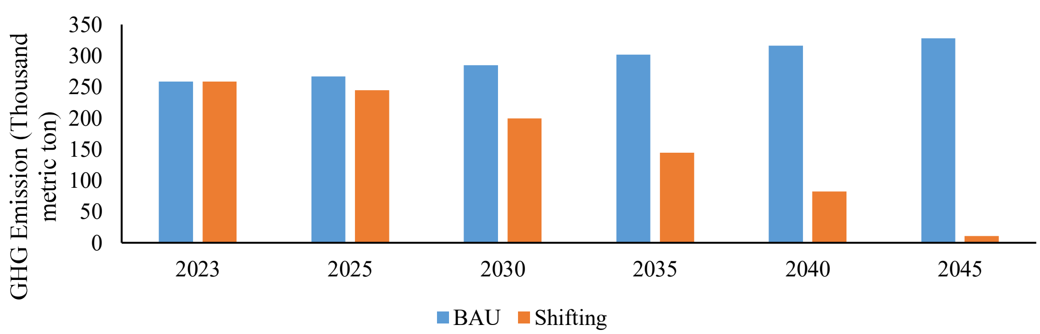


Figure 5.3: GHG emission in residential sector of Kathmandu Valley

5.4.2 Commercial sector

Figure 5.4 shows the energy demand in Business as Usual (BAU) and shifting scenarios. This shows that the demand of energy decreases in shifting scenario than in the BAU scenario as the use of more efficient technology is done in shifting scenario. The total energy demand in year 2045 would be 4.08 PJ and 1.91 PJ in BAU scenario and shifting scenario respectively.

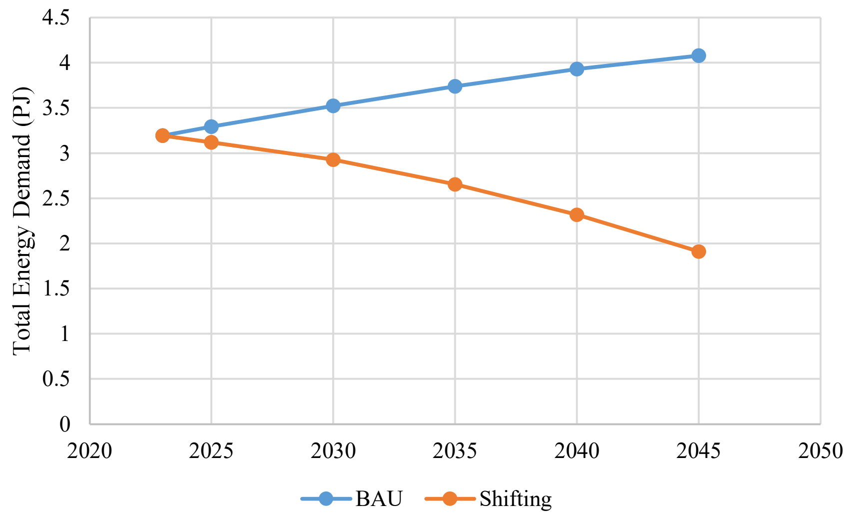
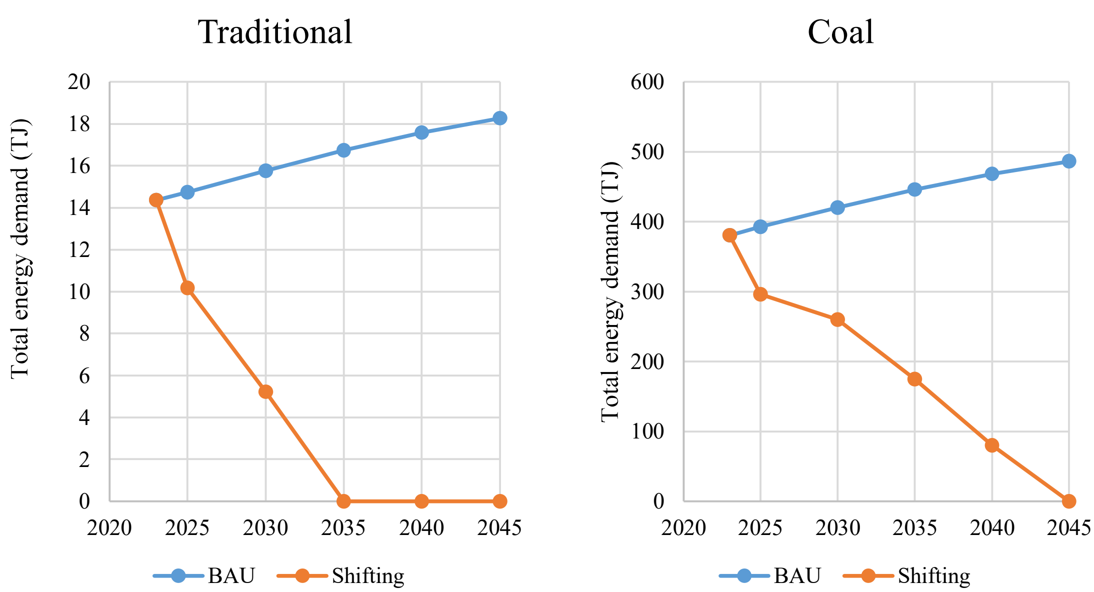


Figure 5.4: Total final energy demand in commercial sector

The Figure 5.5 shows the fuel wise comparison of the energy demand in BAU and shifting scenarios.



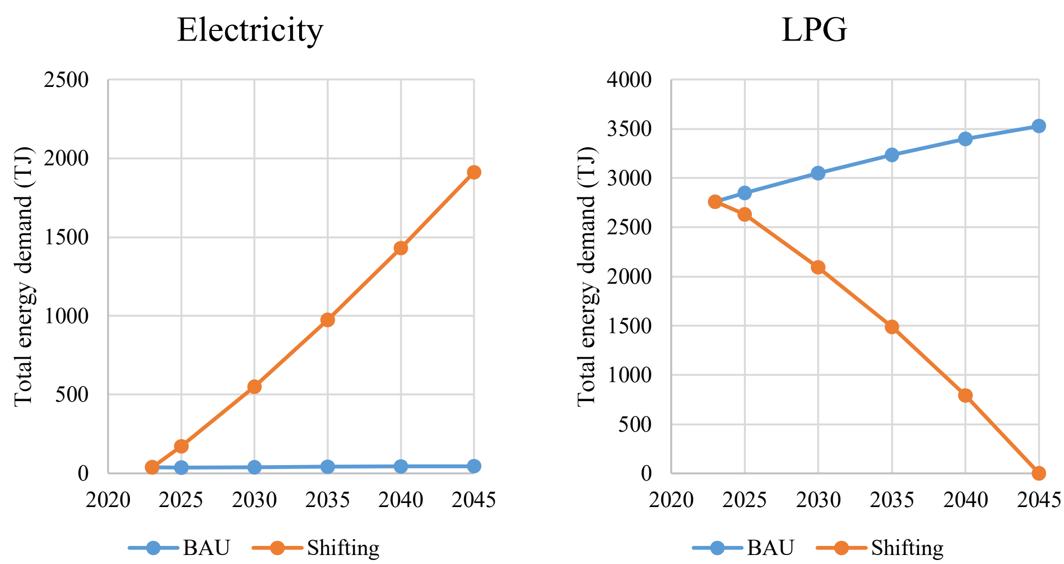


Figure 5.5: Fuel wise comparison

Figure 5.6 shows the GHG emission in commercial sector of Kathmandu valley for the BAU and shifting scenario. The production of GHG gas would be in decreasing order in shifting scenarios as the use of fossil fuels and traditional biomass is replaced by clean energy.

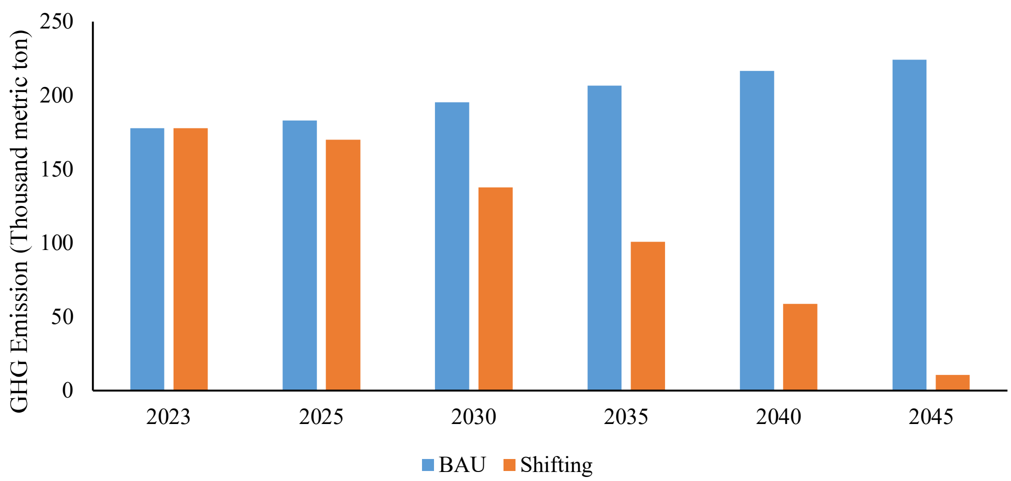


Figure 5.6: GHG emission in residential sector of Kathmandu Valley

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

Residential Sector

- In residential sector of Kathmandu valley, 97.39% of the households use LPG stove while rice cooker is used by 25.09%, biomass cookstove by 13.42%%, and electric stove by 10.19%.
- Regarding cooking fuels, 97.39% of household use LPG, 43.54% use electricity, and 13.42% use fuelwood as the source of fuel for cooking.
- Among the households, 47.79% of household use single type stove, 37.40% use two type stoves while the remaining percentage of household use more than three type stoves. Also, 13.25% of the households used LPG with rice cooker while about 6.35% used biomass stove with LPG.
- It was found that 54.51% of the respondents considered their current cooking technology to be expensive. Furthermore, 16.60% of the participants expressed concerns about the potential risk of accidents associated with their current cooking technology.
- While assessing the willingness to switch during the survey, about 72.36% of the households were in favour of switching to cleaner technologies.
- The major barriers towards shifting were identified as unreliability of electricity along with the low fuse rating used in most of the households. For using electrical cook stove, fuse rating should be higher but in case of residential sector, 19.88% of household are still using 6 A fuse.
- The total final energy consumed in the residential area of Kathmandu Valley is found to be 6735.96 TJ while the total useful energy consumed is found to be 2727.5 TJ.
- In residential sector of Kathmandu valley, for the BAU scenario, the energy demand is expected to be 6942.39 TJ for year 2025. Further, in years 2035 and 2045 the energy demand is expected to reach 7889.08 TJ and 8617.48 TJ respectively. For the shifting scenario, the energy demand is expected to be 6419.38 TJ for year 2025. Further, in years 2035 and 2045 the energy demand is expected to reach 5180.97 TJ and 4335.60 TJ respectively.

Commercial sector

- In commercial sector of Kathmandu valley, 96.03% of commercial entities are using LPG for cooking while 14.04% of commercial entities use electric cook stove, also, electric kettle, rice cooker, and biomass cookstoves were used by 10.86%, 11.66%, and 6.62% entities respectively.
- Regarding cooking fuels, 96.03% of commercial entities use LPG while electricity, and fuelwood is used by 35.17%, and 6.62% of commercial entities respectively for cooking.
- Among the commercial entities 62.25% uses single stove, 27.22% entities use two type stove and the remaining percentage of entities use three or more type stove. On the other hand, 60.07% use one type fuel while 35.56% use two type fuel and the remaining percentage of commercial entities use more than two type fuel for cooking.

- While assessing the user perception, 32.05% of the respondents regarded their cooking technology as time consuming. Further, it was found that 24.42% and 23.96% of the respondents considered their current cooking technology expensive to maintain and operate.
- While assessing the willingness to switch during the survey, 57.48% of the households were in favour of switching to cleaner technologies.
- Most of the respondents who were not willing to shift towards new technology has issues with the compatibility aspects of utensils with new cooking technologies.
- The major barrier on shifting towards electric cooking technology is fuse rating as for using electrical cook stove, fuse rating should be higher but in case of commercial sector, 3.51% and 39.40% of the entities were using 6A and 16A fuse respectively.
- The total final energy consumed in the commercial areas of Kathmandu Valley is found to be 3194.33 TJ while the total useful energy consumed is found to be 1495.65 TJ. The specific energy per entity was found to be 107.34 GJ/Entity.
- In commercial sector of Kathmandu valley, for the BAU scenario, the energy demand is expected to be 3121.02 TJ for year 2025. Further, in years 2035 and 2045 the energy demand is expected to reach 3740.21 TJ and 4078.62 TJ respectively. For the shifting scenario, the energy demand is expected to be 3121.02 TJ for year 2025. Further, in years 2035 and 2045 the energy demand is expected to reach 2654.99 TJ and 1911.42 TJ respectively.

6.2 Recommendations

On the basis of this study, following recommendations are provided:

- Electricity used for cooking in residential sector of Kathmandu Metropolitan City, Lalitpur Metropolitan City, cluster 3, and cluster 4 are 59.31%, 45.41%, 39.45%, and 34.08% respectively. Similarly, the electricity used for cooking in commercial sector of Kathmandu Metropolitan City, Lalitpur Metropolitan City, cluster 3, and cluster 4 are 50.77%, 41.01%, 23,26%, and 25,60% respectively. From the study, we have also found out that despite the high reliance on LPG for cooking and most respondents have perceived its cost as high. Since, the specific cost of fuel per person per month for electricity is less than LPG. To encourage cost savings, it is crucial to raise mass awareness about utilizing electricity as the primary cooking technology.
- In the residential sector of Kathmandu Metropolitan City, Lalitpur Metropolitan City, cluster 3, and cluster 4, a significant number of households (17.37%, 23.88%, 7.44%, and 30.77% respectively) are using 6A fuses, while in the commercial sector, the percentages are much lower (1.28%, 2.25%, 5.94%, and 4.53% respectively). To address this, it is necessary to upgrade the electricity connections to at least 16A. Furthermore, upgrading the transformers and distribution systems is essential to ensure a smooth and uninterrupted power supply, avoiding any potential issues. The Government of Nepal should actively encourage the adoption of 16A fuses by offering suitable financial incentives and support.
- Since most people want to switch to newer cooking technology because they believe that using electricity will be cheaper than LPG, it is essential to make electricity tariffs more affordable, enabling households to afford electricity not only for lighting but also for cooking purposes. By ensuring affordable electricity prices, more people will be incentivized to switch to electricity as a viable and cost-effective cooking option, promoting a shift towards sustainable and efficient energy usage.

- The socio-cultural values deeply embedded in traditional cooking systems, such as the use of fuelwood, present challenges in adopting newer cooking methods for certain ethnic groups. To address this, it is crucial to provide comprehensive awareness campaigns that educate and familiarize these communities with the benefits of transitioning to modern cooking technologies. By highlighting the advantages of newer cooking habits, such as improved efficiency, reduced environmental impact, and enhanced convenience, individuals can make informed choices that align with their cultural values while embracing the advantages of alternative cooking methods.
- To facilitate the widespread adoption of clean cooking technologies, it is imperative to establish local government policies and regulatory procedures. In order to assist those in need, subsidies for clean cooking should be made available, ensuring accessibility for both homeowners and individuals living in rented accommodations. Furthermore, offering financial incentives such as reduced customs duties and exemptions from value-added tax (VAT) to both can significantly encourage the transition to clean cooking technology. Furthermore, the government should establish provisions to distribute electric cook stoves specifically to households with 16A or higher fuses, with a special emphasis on prioritizing women-owned households and marginalized groups. The Government of Nepal can also make provisions to allow commercial entities to install their separate feeder/three-phase connection to facilitate greater electricity use.
- According to the survey, the prevailing concern among households and entities is the unstable electricity supply and frequent power cuts, which hinder the promotion of electric cooking. To encourage the adoption of electricity as the primary cooking source, it is essential to prioritize and improve the reliability of electricity. By addressing the issues related to power stability and reducing interruptions, people will feel more motivated and confident in utilizing electricity for cooking purposes, leading to a greater acceptance and uptake of electric cooking technologies.
- Considering the future inclination of a majority of respondents to switch to electric cooking technologies, specifically induction stoves, it is crucial to anticipate potential maintenance challenges. It is important to organize training programs for induction stove repairs to address the issue. By providing proper training, individuals can acquire the necessary skills to handle and troubleshoot issues related to induction stoves, ensuring their efficient operation. It is recommended that the government of Nepal takes the initiative in organizing these training programs, enabling users to confidently maintain their induction stoves, maximizing their longevity and minimizing any potential setbacks associated with maintenance. Additionally, the government should organize programs aimed at distributing utensils that are compatible with electric cookstoves. This initiative will help eliminate the barrier caused by inadequate utensils that are not suitable for such cookstoves.
- Emissions from traditional cooking methods, such as burning solid fuels, contribute to indoor and outdoor air pollution, leading to adverse health effects, especially for women and children who are often exposed to high levels of pollutants. It is recommended that the Government of Nepal takes the initiative to implement regulations on emission standards and establish limits on the amount of pollutants that cooking technologies can emit.

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