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Electricity Demand Creation in Residential Sector of Nepal

By

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A THESIS

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The undersigned certify that they have read and recommended to the institute of engineering for the acceptance, a thesis entitled "**Electricity Demand Creation in Residential Sector of Nepal**" submitted by Shashwat Adhikari (076MSMDE017) in partial fulfillment of the requirements for the degree of Master of Science in Mechanical system design and engineering.

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ABSTRACT

This thesis examines how the residential sector of Nepal generates demand for electricity. It examines consumption patterns, demand-stimulation techniques, infrastructure and affordability issues, and the negative effects of rising demand. To achieve sustainable growth in power demand, the study emphasizes the importance of continuous regulations, community involvement, and technology improvements.

Due to urbanization, population expansion, and rising living standards, energy demand in Nepal's residential sector is rising. In this thesis, the intricate processes of creating electricity demand in Nepal's residential sector are examined, with an eye toward potential implications for sustainable energy management. Through surveys, interviews, and reviews of the literature, the study uses a mixed-methods approach to combine quantitative data analysis and qualitative assessments.

Nepal is also converting to using electricity as a source of renewable energy for consuming energy. In the energy sector, Nepal only accounts for 8.87% of the total use of power, which is quite low compared to wealthy countries. The LEAP energy model tool is used to project the electricity demand from the base year of 2021 through 2045. With 2021 as the base year, business as usual and policy scenarios with low, medium, and high growth rates are taken into consideration to predict power demand.

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ABBREVIATIONS

BAU	Business-as-Usual
NEA	Nepal Electricity Authority
GDP	Gross Domestic Product
LEAP	Low - Emission Analysis Platform
SDG	Sustainable Development Goals
TWh	Terawatt - hour
GJ	Gigajoule
kWh	Kilowatt - hour
PJ	Petajoule
CAGR	Compound Annual Growth Rate
WECS	Water and Energy Commission Secretariat
IPP	Independent Power Producers
IFC	International Finance Corporation
OECD	Organization for Economic Co-operation and Development
GHG	Green - House Gases
O&M	Operation and Management

CHAPTER ONE: INTRODUCTION

1.1. Background

Nepal, a landlocked nation in the Himalayas with abundant natural resources, including potential for hydropower, still confronts considerable difficulties in satisfying its energy needs. The energy sector of the nation has been characterized by a high reliance on conventional energy sources, such as biomass and fossil fuels, which are inefficient and damaging to the environment. The residential sector, which consists of homes and small enterprises, is essential to energy consumption because it accounts for a sizeable amount of Nepal's overall energy demand. The consumption of energy is taken as an indicator for the measurement of level of development in any region. An economic survey indicates that the usage of non-commercial forms dominates Nepal's overall energy consumption. Over the past ten years, energy consumption has increased at a 4% annual pace (MoF, 2021). As more contemporary energy sources are used, traditional energy usage decreases from 84% in 2010 to 67% in 2020. Commercial energy sources (coal, petroleum products, and electricity) are gradually taking over, increasing their share from 15% in 2010 to 31% in 2020, a rise of 12% growth annually. Renewable energy sources are also developing steadily, with their contribution rising from 1% in 2010 to 2% in 2020. From 2% a decade ago, power consumption has recently grown to 4%. Due to population expansion, urbanization, changing lifestyles, and economic development, the demand for energy in the residential sector has been rising significantly. The demand for electricity and other forms of energy to power various household appliances and technological gadgets is rising as more people relocate to metropolitan regions in search of better employment prospects.

The sector with the largest energy use is still the residential one. Residential energy use in 2021 was 396 PJ, or 64% of total national energy use. Although the residential sector's overall energy consumption has increased over the previous decade, the sector's energy intensity has reduced from around 14 GJ per capita to 13.2 GJ per capita in 2019.Energy consumption climbed at a pace of 2.2% per year in the last two years in the residential sector, which accounts for 64% of all energy consumption in Nepal, outpacing the rate of population growth. With an 85% share in this industry, fuelwood continues to be the energy source most frequently used. In the last ten years, the percentage of LPG consumption has more than doubled to 2.8%. Additionally, the share of renewable energy, primarily biogas has grown to 2.5% and that of solar to 0.5%. Like that, from 1% in 2009, electricity use rose to 3%. Over the previous ten years, the residential sector's energy intensity has declined, from over 14 GJ per person in 2009 to 13.2 GJ per person in 2019. This demonstrates the effects of clean energy technology penetration as well as current energy access. The progressive transition to clean energy with the adoption of more effective electric technology was also evidenced by the rising trend in household electricity per HH. In 2021, the amount of electricity consumed per person, including that from alternative energy sources, will have climbed to 265 kWh. But compared to the South Asian average, this is still the lowest. More attention needs to be paid to electrification if the government is to accomplish its goal of increasing per-capita power usage to 700kWh by 2022/23.

With a rising trend, Nepal has made tremendous progress in recent years in increasing the capacity of its energy production. The annual growth rate of energy generation during the previous five years has been a remarkable 16.29%, and the growth rate over the previous ten years is still high at 10.63%. Notably, last year alone had a significant increase in electricity generation of 57.50%. This encouraging development is a result of Nepal's persistent attempts to use its plentiful water and energy resources to satisfy the country's rising energy needs. In parallel, Nepal's use of electricity has also been growing rapidly, with an average annual growth rate of 27.39%. The nation's overall development is demonstrated by the growth rates for the last five and ten years, which are 10.87% and 11.43%, respectively. These figures reflect the rising energy needs in different economic sectors.

Even though both power production and consumption are expanding significantly, electricity production is doing so faster than consumption. This implies that there might be more electricity available than there is currently demand in the future. To deal with this situation, it is essential to concentrate on increasing the demand for power, making the most of the additional generation capacity, and maintaining the long-term viability of Nepal's energy industry. The project "Electricity Demand Creation in Different Sectors" aims to find and put into practice strategic initiatives that support national goals. With the help of this extensive endeavor, Nepal hopes to make the most of its energy supplies, lessen its reliance on imported fossil fuels, and pave the path for a future that is more electrified and resilient. The thesis highlights the importance of educated policy choices and discusses strategies for achieving the country's energy goals responsibly and effectively.

1.2 Problem statement

In Nepal, it is seen that the sector with the largest energy use is still the residential one. Residential energy use in 2021 was 396 PJ, or 64% of total national energy use. With the increase in new technologies, the use of electricity for residential purposes is also increasing but the pace of replacing the old technology is not sufficient yet. The main sectoral goals include energy generation between 1,400 and 15,000 MW, of which 5–10% will come from mini- and micro-hydropower, solar, wind, and bioenergy. By 2025, it hopes to see 25% of residential households using electric cooktops, with upgraded stoves installed in rural regions and a focus on both household and institutional biogas plants. Due to rising population, urbanization, and better living conditions, energy demand in Nepal's residential sector is significantly increasing. However, several issues make it difficult to effectively control the demand for power in residential areas. These difficulties include a rising demand that puts a strain on the infrastructure already in place, An uneven distribution of electricity, a reliance on non-renewable energy sources, a lack of energy efficiency measures, insufficient grid management, complex pricing issues, and legislative and regulatory restrictions. To encourage sustainable power demand creation, improve energy efficiency, and guarantee dependable access to electricity in residential sectors across Nepal, this research offers doable solutions. Also, overall projection of energy demand is not studied properly.

The study aims to contribute to the nation's socioeconomic development, environmental sustainability, and energy security by addressing these issues.

1.3 Research Gap

Residential families consume 43.3% of the electricity, according to the Nepal Energy Sector Synopsis Report 2022. Academics, academics organizations, and governmental entities have conducted relatively little research on how Nepal's residential sector generates power demand. The long-term goal for 2050, according to the WECS study from 2013, calls for fostering a quick transition to practical, new, and alternative energy sources in the urban residential, commercial, and industrial sectors across the nation. The energy efforts that need to be planned for part of SDG include large hydropower projects, micro hydro off-grid, grid-connected solar systems, transmission and distribution systems, greater energy efficiency, and O&M costs to assure a consistent quality of power supply. Therefore, the conversion to electrical appliances in this sector has become a research area. There isn't much literature that addresses this. They concentrate on total electricity and energy usage. There is little research on how to increase power consumption in the household sector.

1.4 Objectives

1.4.1 Main Objective

The main objective of this thesis is to analyze growth in electricity consumption in residential sector of Nepal from 2021 to 2045.

1.4.2 Specific Objectives

The specific objectives of this thesis are:

- To determine the present status of energy consumption in residential sector of Nepal
- To estimate the energy demand of energy consumption up to 2045 AD in residential sectors
- To compare different energy scenarios in residential sectors of Nepal
- To help transitions from a conventional to an electrical mode of operation cheaply and effectively.

1.5 Limitation

The sole thing being studied in this research is how to increase demand in the residential sector. Other industries, such transportation, industry, agriculture, etc., have not been covered. Other industries, unrelated to the ones being investigated for the thesis, could potentially electrify. In a similar vein, demand creation does not only depend on an all-electric future. Additionally, rather than primary sources, the data were gathered from secondary sources like web publications. The emission standards are not covered.

CHAPTER TWO: LITERATURE REVIEW

Every nation's progress depends heavily on its access to energy. The economy of the country and energy consumption are intertwined. A nation's progress is gauged by how much energy it uses. The demand for energy will increase as the country's economy and population grow. There are numerous types of energy that come from various sources. According to the results of an economic survey, all the different energy sources used in Nepal are categorized in Figure 2.1. It can be broadly divided into traditional, commercial, and renewable categories. Here, electricity is classified as a fuel or commercial good.

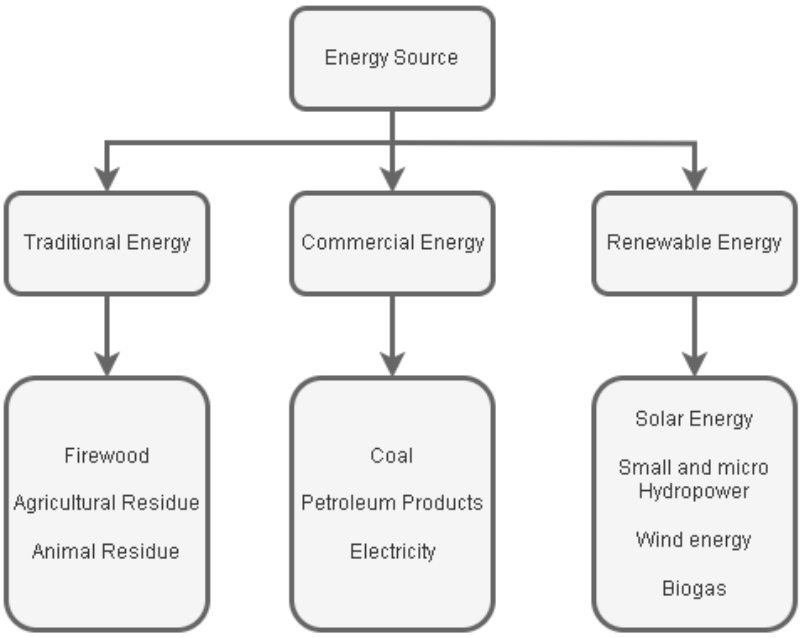


Figure 1: Classification of energy

The population density, economic activity, technical advancement, climatic conditions, energy prices, and other factors all play a role in the amount of energy consumed. Implementing energy-efficient technologies, encouraging behavioral changes, and adopting renewable energy sources are the main goals of energy management. This strategy tries to reduce costs while minimizing the impact on the environment. The development of the residential sector is essential for economic growth. Therefore, the world's energy networks are greatly impacted by the demand for electricity. With the rise in global energy consumption, the production of power demand within households is becoming a more important research topic. Consequently, increased domestic power use can significantly affect both sustainability and total energy efficiency. Furthermore, as the world moves toward cleaner and renewable energy sources, employing renewable energy in household operations has become more and more important. Since domestic production of energy is more

cost-effective than exporting it to countries like Bangladesh and India, it is crucial to increase national demand for it.

2.1 Energy Consumption Pattern

One of the main factors influencing energy use, particularly in the residential and transportation sectors, is demography. The Central Bureau of Statistics' preliminary report from 2021 estimates that the country's population will total 29,192,480, with a growth rate of 0.93% from 2011 to 2021. In comparison to the previous household size of 4.88 in 2011, the national household size in 2021 was 4.32. According to CBS, around 66% of Nepal's population lives in urban regions while the remaining 34% still stay in rural areas. With 21% of the total population apiece, the Bagmati and Madhesh provinces have the highest populations, followed by Lumbini, Province 1, Sudurpashchim, Gandaki,and karnali province.

In Nepal, biomass serves as the main energy source, with electricity, coal, and petroleum serving as secondary sources. The total energy consumption has climbed to 11.8 million tons of oil equivalent, with a 3% annual growth rate, according to an economic survey conducted in 2015–16 (MOF, 2016). According to the WECS 2013 study, residential regions use about 80% of all energy, followed by industrial areas at 8%, transportation at 7%, business at 3%, and agriculture at 1%. A little over 63% of fuel in commercial sources in 2014–15 came from petroleum products, 17% from electricity, and the rest from coal (Clean Energy Nepal, 2019). The International Energy Outlook (2013) predicts that between 2010 and 2040, the world's energy demand would rise by 56% (Azad et al., 2014). According to the NEA annual report from 2020, the domestic sector consumed the most electricity in FY 2019–20, accounting for 44.34% of the total. The industrial sector came in second with 35.83% of the total, followed by the commercial (7.59%), non-commercial (2.97%), and other sectors (9.27%). Rural residential sector uses fuelwood, agriculture residue, animal waste, biogas, and another biomass. Solar and hydro energy sources are used in urban areas, mainly for cooking and lighting. There are several factors that contribute to the level of energy consumption which are the size of the population, economic activity, technological progress, climate conditions, energy prices etc. The primary objective of energy management is to implement energy-efficient technologies, promoting behavioral changes, and embracing renewable energy sources. This approach aims to minimize the environmental impact and cut down on costs. Table 2-1 shows that more fuelwoods will be consumed in the residential sector's energy consumption from 2019 to 2021. The table below illustrates the residential sector's energy consumption from 2019 to 2021, with fuelwood use peaking in 2021 at roughly 335420.90 GJ. In 2021, 11668.28 GJ of energy will be consumed as electricity, up from 9075.49 GJ in 2019.

The consumption of energy in the residential sector is given in the table below. It was found that cooking consumes 79.566% of energy which is very high compared to another sectors. It is because of lack of electrification in urban cooking where firewood is still the dominant fuel used.

Table 2-1:Fuelwise energy consumption in residential sector (TJ)

	2019	2020	2021
Fuelwood	322,597.14	326,862.63	335,420.90
Agricultural Residue	7,208.31	7,278.95	7,350.28
Animal Waste	18,840.60	17,877.64	17,967.02
Kerosene	175.55	166.79	175.82
Petrol	-	-	-
Diesel	-	-	-
ATF	-	-	-
LPG	10,390.15	10,860.65	10,899.78
Furnace Oil	-	-	-
Coal	-	-	-
Electricity	9,075.49	9,977.37	11,668.28
Biogas	8,134.60	10,095.74	9,705.28
Bio-briquette	-	-	-
Solar	1,889.96	1,895.68	2,010.59
Wind	1.04	1.42	1.87
Micro/Pico Hydro	325.94	435.89	514.96
	378,638.78	385,452.76	395,714.78

Only 0.4% of cooking is done using electricity and Nepal has possibility to switch into electric medium in future years. Similarly, water boiling consumes 2.136% of energy also space heating consumes 0.57% of energy, space cooling consumes 1.32768% of the energy, lighting consumes 1.2556% of energy, electrical appliances consume 3.453% energy and other end use uses 11.689% of energy.

Fuels/End Use	Cooking	Water Boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others
Wood	75.26	75.83	75.72	0.00	0.00	0.00	79.68
Agricultural residue	5.28	1.47	0.00	0.00	0.00	0.00	2.09
Animal waste	4.41	0.01	0.00	0.00	0.00	0.00	5.51
Coal	0.02	0.02	0.00	0.00	0.00	0.00	0.00
kerosene	0.01	0.00	0.00	0.00	7.91	0.00	0.06
LPG	12.21	15.30	0.91	0.00	0.00	0.00	11.38
Electricity	0.40	2.02	22.82	100.00	86.15	100.00	0.07
biogas	2.40	0.66	0.00	0.00	1.29	0.00	1.13
briquettes	0.01	0.00	0.55	0.00	0.00	0.00	0.09
Solar thermal	0.00	4.69	0.00	0.00	0.00	0.00	0.00
Solar PV	0.00	0.00	0.00	0.00	4.65	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

2.2 Electricity Generation

About 2130 MW of energy is being produced in Nepal through IPPs, NEA, and its subsidiaries, and 3260 MW of electricity is currently being produced through hydropower stations that are currently under development. 11064 GWh of electricity will be produced in Nepal overall in 2022, of which 3259 GWh will be produced by NEA, 1976 GWh will be acquired through subsidiaries, 4286 GWh will be acquired from independent power producers, and 1543 GWh will be imported from India. In Nepal, 9,316 GWh of electricity were sold in total in 2022.Nepal's whole installed capacity will be sufficient to supply energy at peak demand by 2022. Over time, there has been a considerable increase of consumers.

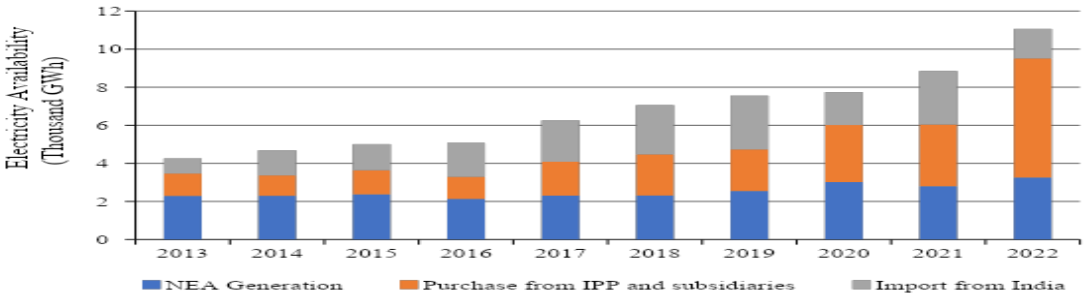


Figure 2-2: Energy Availability Status

2.3 Transmission Distribution Status

The nation's electrical supply is created, distributed, managed, and maintained in Nepal by the Nepal Electrical Authority. With a capacity of almost 83000 megawatts, our country has the highest potential for producing electricity only from hydropower. The planning, construction, and maintenance of transmission lines, related sub-stations, and necessary modifications and reinforcements to already-existing ones are among the responsibilities of the transmission directorate. The table below compares the length of transmission lines and illustrates how the above completed projects demonstrate the steady and progressive status in the transmission sectors:

Table 2-2: Comparison of Transmission Line Length

S.N.	FY	Circuit km				Total	Total Increment ckt. km)
		66 kV	132 kV	220 kV	400 kV		
1	2071/072	494	2130			2624	
2	2072/073	494	2417			2911	287
3	2073/074	494	2596	75	78	3243	332
4	2074/075	514	2717	75	78	3384	141
5	2075/076	514	3142.5	255	78	3989.50	606
6	2076/077	514	3240	437	78	4269	279.50
7	2077/078	514.00	3540.54	741.20	78	4874	604.74
8	2078/079	514.00	3816.54	896.60	102.00	5329	455.40
Total Increment in Eight Years							**2705.44**

2.4 Electricity Consumption Scenario

A WECS research estimates that the total power usage of 2021 was found to be 7313 GWh has increased significantly over the previous 25 years by almost 10 times, from 328.72 GWh to 3241.189 GWh, from 1996 to 2021 in residential sector. According to the report of energy synopsis 2022, the residential sector accounted for the highest consumption at 44.24% of electricity consumption, followed by the industrial sector at 38.54%, and the commercial sector at 14.41%.

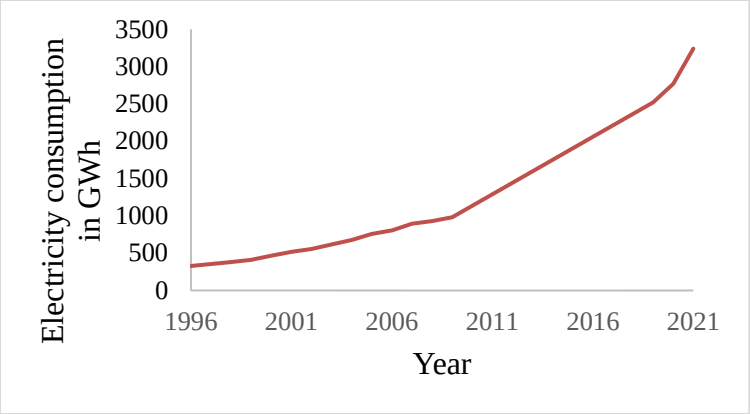


Figure 2-3: Electricity consumption in residential sector

The Compounded Annual Growth Rate (CAGR) calculated is 9.586% , which indicates that the consumption of electricity is growing in this rate. The residential sector increased the fastest, followed by the industrial sector. So, this shows electricity demand creation in residential sector.

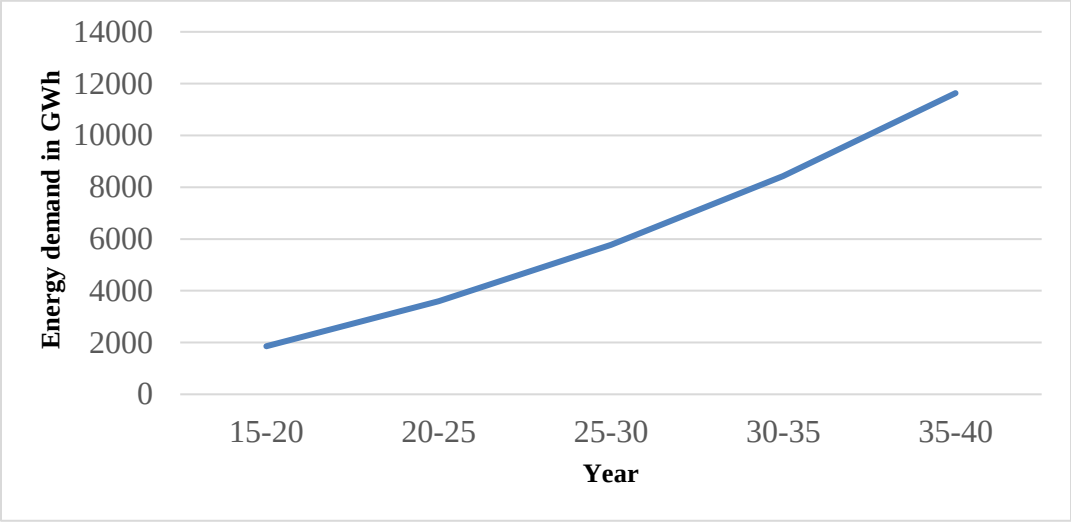


Figure 2-4 Electricity demand projection

It is found that there is an increasing trend of electricity demand. This is from 2015 to 2030 when energy demand increased in the form of electricity. The demand has risen from 1847.52 GWh to 11632.15 GWh in 2030 during its peak hour. So, this demand also includes the residential sector where it is high demand for the operation of components which run through electricity.

2.5 Technologies in Residential sector and Electricity Consumption

The six end uses in each residential sector are cooking, water boiling, space heating, space cooling, lighting, electrical appliances, and others. To obtain a sustainable goal and mitigate climate change, it is necessary to switch to an electrical medium. Some of technologies with their end use is given below.

Table 2-3:Technologies used in residential sector.

End use	Technologies
Cooking	Induction stoves. Microwaves, rice cookers, hot plate stove, infrared stove, air fryer
Water boiling	Electric kettles, electric jug, immersion rods
Space heating	Air conditioners, halogen heaters, blowers
Space cooling	Air conditions, coolers, fan
Lighting	CFL bulbs, fluorescent lamp, LED lamps, Halogen lamps
Electrical appliances	Iron, washing machines, dishwashers, mixers

So, there is high possibility for switching the traditional residential equipment into electrical ones.

Table 2-4 Efficiencies of technologies used in residential sector

Fuel/ End use	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others
Wood	15	25	45	15	25	25	15
Agricultural residue	15	25	45	15	25	25	15
Animal waste	15	25	45	15	25	25	15
Coal	30	40	55	20	30	30	25
kerosene	45	45	75	45	40	40	40
LPG	55	55	75	55	40	45	55
Electricity	90	90	90	90	90	90	90
biogas	40	45	70	30	60	40	45
briquettes	30	30	55	40	30	45	30
Solar thermal	75	75	75	75	75	75	75
Solar PV	75	75	75	75	75	75	75

2.7 Policy Overview

For the promotion of electricity and electricity-based technologies in Nepal, the Government of Nepal has developed several papers and publications with the assistance of various development partners. The following are some plans and policies relating to the creation of electricity demand:

2.7.1 Sustainable Development Goal

The Sustainable Development Goals (SDGs), Status and Roadmap: 2016–2030 report states that Nepal has the chance to meet its energy requirements through clean hydroelectricity, which will help to provide consumer goods at reasonable prices, boost the competitiveness of Nepali businesses, and enable the nation to switch to clean energy. Nepal has set itself the goal of rising from the least developed to the medium developed countries during this time, aiming for a ten-year period of rapid economic development of over seven percent.

- Raising the percentage of people who have access to electricity to 99% by 2030.
- An increase in the amount of electricity consumed per person, reaching 1,027 kWh in 2025 and 1,500 kWh in 2030.
- Increasing the installed hydropower capacity to 15,000 MW in 2030 and 10,260 MW in 2025.
- A rise in the percentage of electric vehicles used in public transportation, from 1% in 2020 to 35% in 2025 and 50% in 2050.

2.7.2 Second Nationally Determined Contribution, 2020

- Increase clean energy production from 1400 MW to 15000 MW by 2030, with 5- 10% of the energy coming from mini and micro hydropower, solar, wind, and biofuels. Among these, 5,000 MW is the unwavering goal. The provision of financing by the global community is necessary for the remaining amount.
- By 2025, sales of electric vehicles will account for 20% of all four-wheeled public passenger vehicle sales and 25% of all private passenger vehicle sales, excluding rickshaws and electric tempos. This percentage includes both two- and four-wheeled vehicles.
- Sales of electric vehicles will reach 90% of all private passenger two-wheelers and 60% of public passenger four-wheelers by 2030, excluding e-rickshaws and e-tempos.
- Create a 200-kilometer electrified rail network by 2030 for use in both freight and public transportation.

CHAPTER THREE: METHODOLOGY

3.1 General

The flowchart given below describes the general methodology of this project.

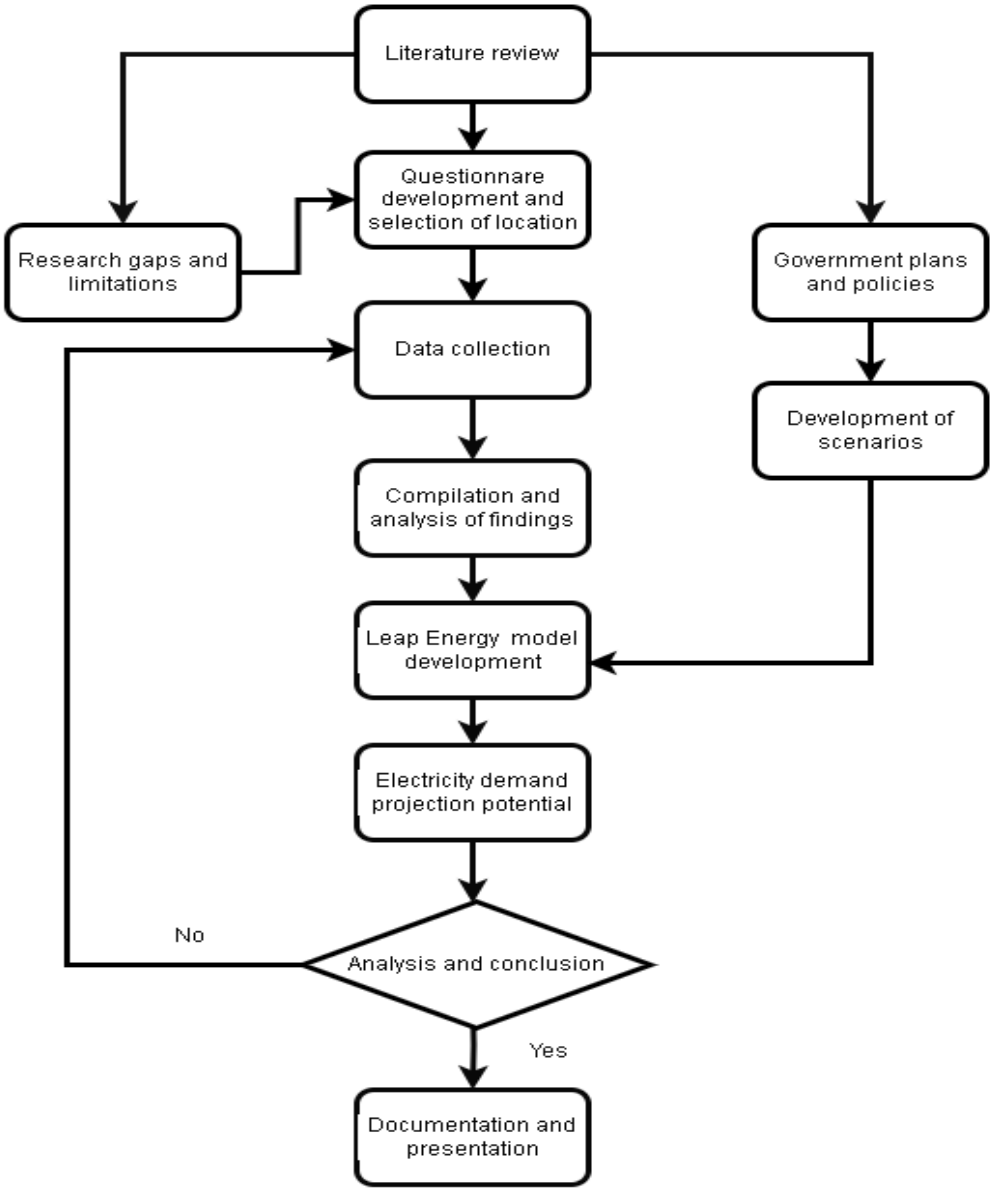


Figure 3-1: Methodology Flowchart

3.2 Data collection

The report from various governmental agencies was employed as a source of information. The data from the real office was difficult to obtain because of regulatory regulations and unavailability of exact data and personnels of related field. Therefore, the data's source is the report, yearbooks and yearly handbooks that were published on their organization's official website. Reports and publications, primarily from government agencies like the Central Bureau of Statistics (CBS), Nepal Electricity Authority (NEA), Alternative Energy Promotion Center (AEPC), and the Water and Energy Commission Secretariat (WECS), as well as other NGOs and INGOs, were studied and are included. The data and information collected are presented below:

- Information related to residential households in provinces One, Two and Three was collected.
- Since the information of other provinces was not available the information and data of other provinces were projected using the past data and previous publications.
- Pattern of electricity consumption of three provinces.
- Plans and policies regarding the electricity demand and supply in the residential sector projected for the future.

3.3 Modeling

Energy demand modeling is a crucial component for energy planning, strategy formulation, and policy suggestion. For the examination of the energy situation, numerous energy models based on diverse approaches are available. However, given the varied energy plans and policies, choosing an energy model might be complex. The most popular medium to long-term energy model for predicting energy demand is MAED. The model follows the standard procedures for an engineering economy model's end-use demand forecasting. It depends on the methodical creation of consistent demand prediction scenarios in which the socioeconomic and technological aspects are taken into clear consideration. The model clearly accounts for structural changes and market evolution in the end-user demand markets over the scenarios. For the conversion of energies, the demand is first computed in terms of useful energy, and then the final demand is obtained while taking market penetration and end-use efficiency into account. MARKAL is a general model that is included in the input data to describe the evolution of a specific energy system over a long period of time, often 40 to 50 years, at various levels (national, regional, state or province, or community). It employs optimization methodology and is a bottom-up energy model. This energy model's goal is target-oriented and incorporates energy analysis and planning using a least-cost strategy. In this model, the energy requirements are exogenously supplied, and the energy supply is also examined. Low - Emission Analysis Platform often known as LEAP, is a flexible modeling framework that enables the development of tailored applications based on issues at several levels of geography (cities, states, countries, regions, or the world). Given that LEAP is an integrated energy planning model, it may be used for both the supply and demand sides of the energy system. The model called the Low - Emission Analysis Platform (LEAP) System is used to assess the condition of

household electrical systems. It employs a demand- and end-driven methodology, meaning that the study begins with the end use of energy. Its demand branch is broken down into several levels, including sectors, sub-sectors, end-uses, and devices. This model, which is a simulation tool, shows the current energy status in a selected location and projects the future energy demand based on many suppositions, such as population growth and GDP. The current state of the energy system is initially generated by describing data from the base year, and a fundamental scenario is created by assuming that existing trends will continue.

It is the most popular integrated modeling tool and is applicable to all areas of the economy. It details the extraction of resources as well as the production and use of energy. It is also utilized in various industries, including the energy and non-energy sectors, as well as sources and sinks for greenhouse gas emissions (GHG). It is frequently used to assess the impact of air pollution in local and regional locations, which aids in researching the state of the climate. It has been more well-liked and user-friendly over time since complicated energy analysis ideas are simple and easy to implement and process. Different levels of knowledge, from world specialists to decision makers, use this model when they want to communicate the results in a way that is easier and more approachable.

3.4 Description of Scenarios

Business As Usual (BAU) scenario and Policy scenario at different GDP growth rates have been taken into consideration while developing scenarios for the potential future energy consumption using various fuel sources. Different national policies related to demand creation were taken into account such as Second Nationally Determined Contribution (NDC), Sustainable Development Goals (SDG) and Nepal's long term strategy for net zero emission (LTS) were studied. Similarly, these growth rates were calculated using previously published papers and reports from Nepali government agencies. The current energy consumption scenario, end-user technology effectiveness, technological advancement, and economic expansion are key factors. These variables are given to LEAP as input, and the program's output is an estimate of demand for various residential subsectors.

In terms of low, medium, and high growth rates from 2021 to 2050, the average GPD increase is 2.5%, 4.27%, and 6.5%. GPD and population are the major driving factors in growth of households in residential sector. In growth scenario we consider 3 growth scenario low growth, medium growth and high of GDP and household. We took the population elasticity as 1.04 and GDP elasticity as 0.02 and calculated number of households in low GDP growth, Medium GDP growth and high GDP growth. We took the population and population growth rate from UNDESA and projected the population according to population growth rate given on the website. This number of households was used to project the energy demand in the future.

3.4.1 Business as Usual

This hypothetical situation is centered on changing policies without using technology. In this scenario, it is presumptive that typical circumstances will remain constant over time with little shifts in social attitudes. Current average GDP growth rate is considered to meet the demand and supply for electricity according to the nature of the GDP. Here growth rate is derived from the average GDP growth rate between 2011 and 2021 i.e. 4.27%.

3.4.2 Sustainable Development Goal (SDG) scenario

The United Nations created the Sustainable Development Goals (SDGs), a list of global objectives, to solve numerous social, economic, and environmental issues on a global scale. By 2030, these objectives are expected to advance sustainable development and enhance both human and environmental wellbeing. Some of the major targets considered here are:

- The global target for 2030 is to achieve per capita GDP growth of at least seven percent.
- Households using solid fuel as primary source for cooking is targeted to be reduced from 74.7% in 2015 to 55% by 2022, 45% by 2025 and hence 30 % by 2030.
- People using liquid petroleum gas (LPG) for cooking and heating is targeted to increase from 18% in 2015 to 27.8% by 2022 to 32 % by 2025 and 39% by 2030.

3.4.3 Second Nationally Determined Contribution (NDC) scenario

It targets increase clean energy production from 1400 MW to 15000 MW by 2030, with 5- 10% of the energy coming from mini and micro hydropower, solar, wind, and biofuels. Some major targets of NDC considered here are:

- 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.

3.4.4 Nepal's long-term strategy for net zero emission (LTS) scenario

Some of the major targets considered are:

- To achieve per capita GDP growth of at least seven percent by 2030.
- 100% electrification in different end uses of residential sector.

3.4.5 Overall, Policy Scenario

This scenario assumes that technology will be used to influence laws and regulations. In this instance, regular circumstances gradually change over time along with a noticeable shift in people's attitudes. The residential electrification scenario considers a variety of data sources, including the government-developed Sustainable Development Goals (SDG), Nationally Determined Contribution (NDC), and 15th Plan. These give crucial guidance and insights for forecasting

electricity requirements, helping to shape the assumptions regarding electricity adoption in the scenario of household electrification. There are several probable cases that may be obtained after provided below,

- Rural 40% electric, 50% fuelwood and 10% LPG share by 2030, 100% electric by 2050.
- Urban cooking: 100% in electricity by 2030
- Rural and Urban lighting:100% from 2030 onwards to 2050

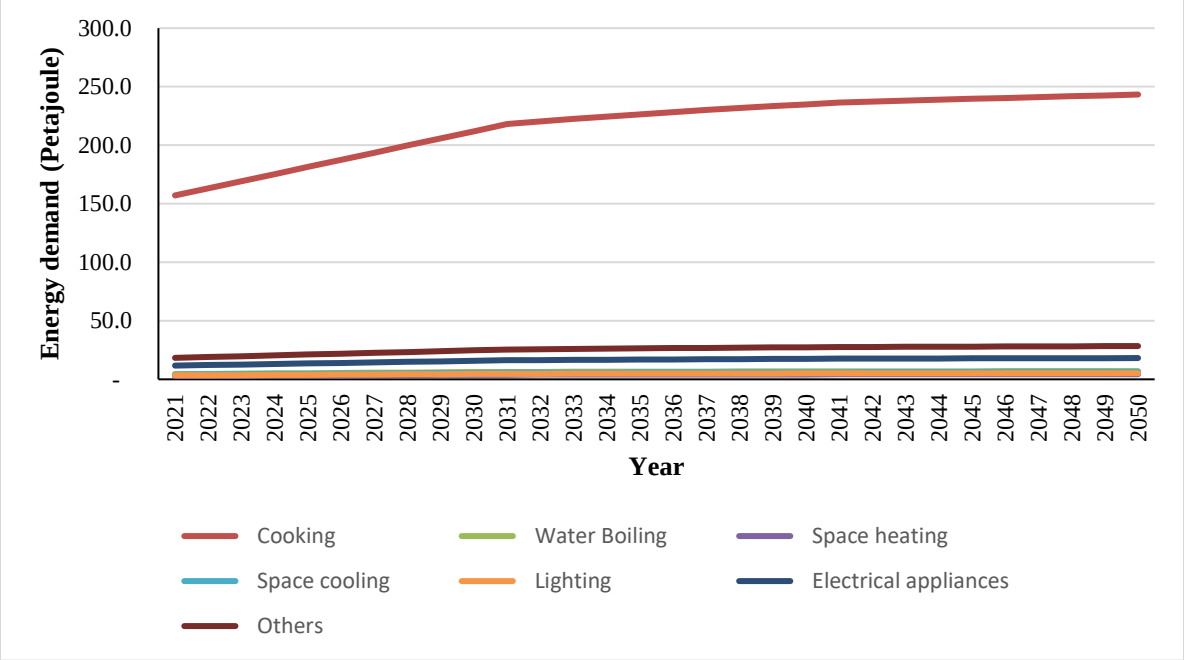
CHAPTER FOUR: RESULT AND DISCUSSION

4.1 Energy Forecasting

4.1.1 Business As Usual (BAU) Scenario

a. Urban BAU Scenario

Within the urban domain, the energy requisites recorded 202.1PJ in the foundational year of 2021, and forecasts indicate an upward trajectory to 312.8PJ within the framework of a current GDP growth scenario. Cooking activities hold sway over urban energy consumption, constituting a considerable proportion. Precisely, the energy expended on cooking activities accounted for 157.1PJ in 2021. Nonetheless, there are compelling indications of a substantial increase to 243.3PJ by the year 2030. This noteworthy rise can be attributed to two interconnected factors: the swift implementation of electrification initiatives and the ongoing migration of rural populations to urban centers.



The sudden increase in energy demand for cooking is principally propelled by the rapid adoption of electrification strategies. These strategies facilitate the transition of cooking practices towards energy-efficient and sustainable modalities, thereby contributing to the observed increment. Furthermore, the ongoing trend of rural populace migration to urban locales significantly shapes this elevation. As rural populations transition to urban environments, the collective energy requisites for cooking intensify within urban settings, consequently contributing to the overall rise in energy demand.

b. Rural BAU Scenario

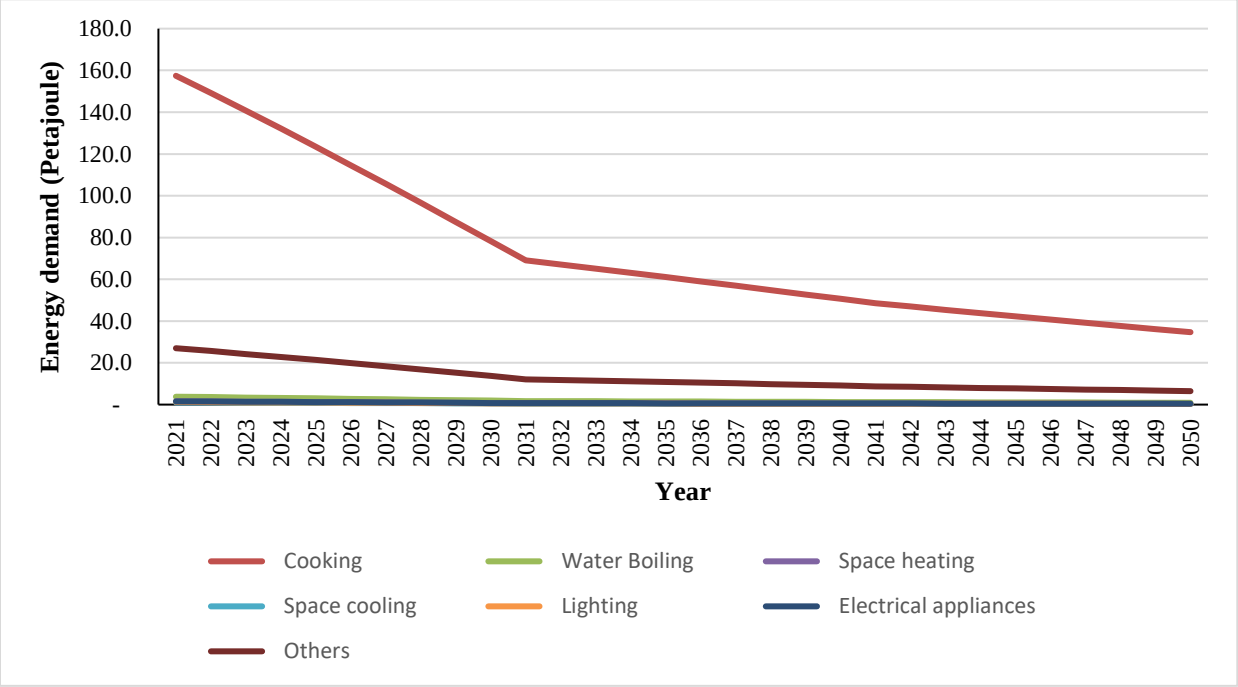


Figure 4-1 BAU scenario for rural residential sector

Within the rural landscape, the energy requisites registered 193.6PJ in the foundational year of 2021, and forecasts anticipate an escalation to 43.3PJ within the scope of a medium growth scenario. Cooking activities significantly influence rural energy consumption, constituting a significant portion. Specifically, energy expended on cooking activities amounted to 157.4PJ in 2021. Nevertheless, there are compelling indications of a substantial reduction to 34.7PJ by the year 2030. This marked decrease can be attributed to two intertwined factors: the prevailing trend in fuel usage and the ongoing migration of populations to urban locales. The distinct decrease in energy demand for cooking is primarily propelled by the prevailing trend in fuel consumption. These shifts facilitate the adoption of more energy-efficient and sustainable cooking practices, thus contributing to the observed reduction. Additionally, the ongoing trend of rural-to-urban population migration significantly influences this decrement. As rural populations relocate to urban areas, the collective energy requirements for cooking decline within rural regions, thereby contributing to the overall reduction in energy demand.

4.1.2 Sustainable Development Goal (SDG) scenario

The households using solid fuel as primary source for cooking is targeted to be reduced from 74.7% in 2015 to 55% by 2022, 45% by 2025 and hence 30 % by 2030 and people using liquid petroleum gas (LPG) for cooking and heating is targeted to increase from 18% in 2015 to 27.8% by 2022 to 32 % by 2025 and 39% by 2030.

a. End use wise demand

i. Urban sector

Due to electrification, the energy required for cooking decreases and hence the electricity demand increases rapidly from 2025 to 2050. In other end uses there is just a slight change in energy demand increasing a bit due to increase in urban population.

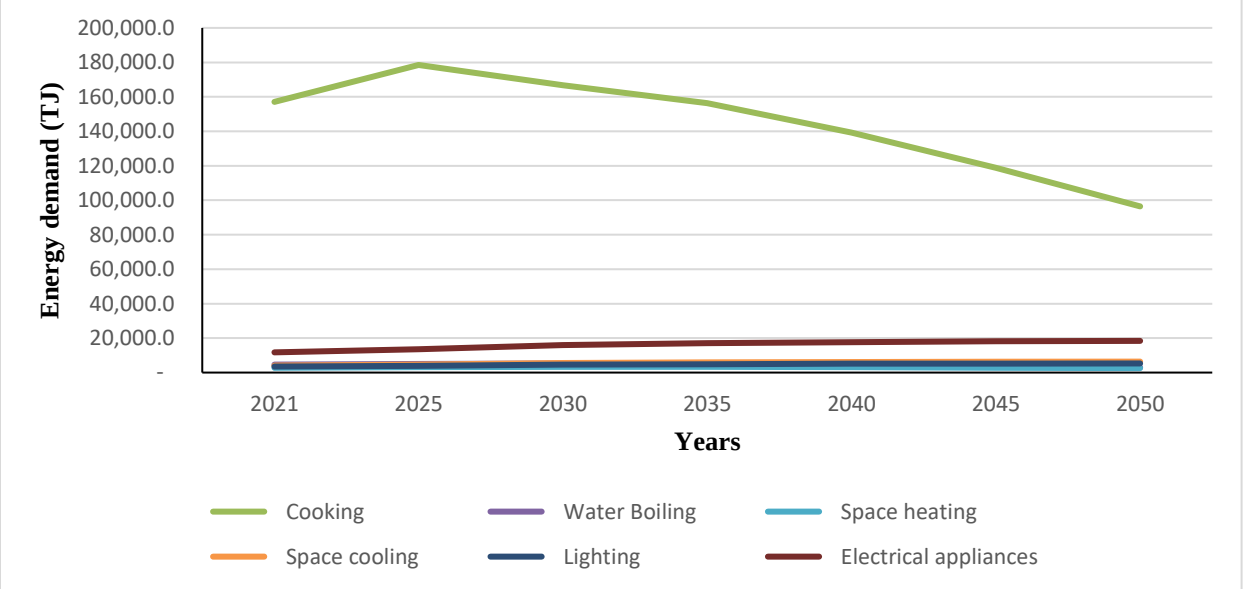


Figure 4-2 Sustainable Development Goals Urban Energy demand scenario

The overall energy demand in cooking is reduced due to electrification in cooking by 2050 and use of electric cookstoves and use of primary source for cooking is targeted to be reduced by 30%.

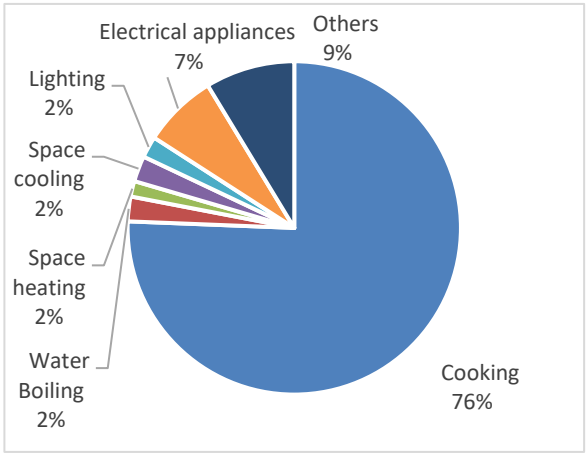


Figure 4-3 Urban sector energy demand 2030 end use wise

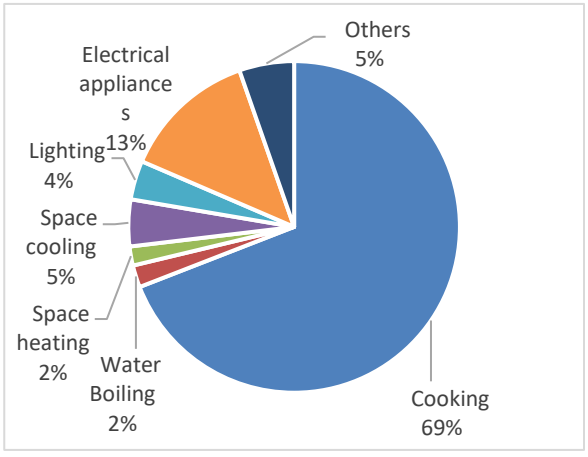


Figure 4-4 Urban sector energy demand 2050 end use wise

The total consumption of firewood is highly reduced from 102683 TJ to 94655.24TJ by 2030 due to the target of reducing solid fuel use for cooking purpose. Similarly, energy from agricultural residue, animal waste and coal are also reduced. And the consumption of LPG increases due to the

target of increasing use of LPG and also the demand of electricity increases from 1071.259 TJ to 11816.11 TJ by 2030 and 19849.51 TJ by 2050.Similarly the use of biogas and briquettes for cooking also decreases significantly and reaches 0 target by 2050.

Table 4-1 Energy demand in urban sector for cooking according to SDG (TJ)

End use/ year	**2021**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**Total**
Firewood	102683.2	122901.2	94655.24	76028.37	52723.05	26962.06	0	475953.1
Agricultural Residue	9995.655	9970.873	9343.796	7505.063	5204.502	2661.533	0	44681.42
Animal Waste	9838.752	9814.359	9197.125	7387.255	5122.806	2619.754	0	43980.05
Coal	45.71335	45.60002	42.73219	34.32307	23.80187	12.17205	0	204.3425
Kerosene	14.08447	14.04955	13.16596	10.57507	7.333449	3.750256	0	62.95875
LPG	30173.21	27070.74	38646.93	48767.36	58402.7	67582.99	76582.7	347226.6
Electricity	1071.259	5398.21	11816.11	14085.17	16139.58	18029.36	19849.51	86389.2
Biogas	3274.431	3266.312	3060.891	2458.549	1704.919	871.8792	0	14636.98
Briquette	19.91522	19.86584	18.61646	14.95299	10.36938	5.30	0	89.0227
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	157116.2	178501.2	166794.6	156291.6	139339.1	118748.8	96432.22	1013224

The use of firewood for boiling reduces from 2884.902 TJ to 2696.765 TJ by 2030 and 0 by 2050 due to 100% electrification target by 2050. Similarly, the use of electric boilers increases hence increasing the demand for electricity from 146.068 TJ to 943.86 TJ by 2030 and 3009.112 TJ by 2050.

Table 4-2 Energy demand in urban sector for water boiling according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	2884.902	2877.75	2696.765	2166.079	1502.101	768.16	0	12895.76
Agricultural Residue	101.7877	101.5353	95.14964	76.42548	52.99843	27.10289	0	454.9994
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	996.9852	994.5133	931.9675	748.5689	519.1067	265.4662	0	4456.608
Electricity	146.0689	452.0169	943.86	1454.602	1974.688	2491.802	3009.112	10472.15
Biogas	31.31277	666.7887	624.8537	501.891	348.0441	177.9864	0	2350.877
Briquette	0.079149	0	0	0	0	0	0	0.079149
Solar thermal	382.2483	0	0	0	0	0	0	382.2483
Solar PV	0	0	0	0	0	0	0	0
	4543.384	5092.604	5292.596	4947.566	4396.937	3730.517	3009.112	31012.72

The use of firewood for space heating decreases from 2305.309 TJ to 2154.969 TJ by 2030. Similarly, the use of LPG is increased since the target is to reduce solid fuel and increase the use of LPG and electricity for heating purpose. The demand for LPG increases from 20.211TJ to 27.39TJ by 2030 and 31.689 TJ by 2050.

Table 4-3 Energy demand in urban sector for space heating according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	2305.309	2299.593	2154.969	1730.901	1200.32	613.8321	0	10304.92
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	20.21142	23.38711	27.39535	29.33908	30.51846	31.2137	31.68952	193.7546
Electricity	473.8436	733.4388	1130.233	1500.751	1863.077	2214.397	2561.739	10477.48
Biogas	0	0	0	0	0	0	0	0
Briquette	12.05347	12.02358	11.26741	9.050134	6.275956	3.209464	0	53.88001
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	2811.417	3068.443	3323.865	3270.041	3100.191	2862.652	2593.428	21030.04

Only electricity is used for space cooling so the electricity demand increases from 4063.407TJ to 5507.702TJ by 2030 and hence to 6371TJ by 2050.

Table 4-4 Energy demand in urban sector for space cooling according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	4063.407	4701.866	5507.702	5898.481	6135.589	6275.364	6371.025	38953.44
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	4063.407	4701.866	5507.702	5898.481	6135.589	6275.364	6371.025	38953.44

The use of kerosene is reduced rapidly for lighting due to almost complete electrification in urban areas. So, the demand of electricity increases from 3202.813TJ to 4484.453TJ by 2030 and 5187.383TJ by 2050.Also the use of solar lighting is increasing, so the demand of solar energy increases from 73.61TJ to 99.778TJ by 2030 and 115.4189TJ by 2050.

Table 4-5 Energy demand in urban sector for Lighting according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	237.766	0	0	0	0	0	0	237.766
LPG	0	0	0	0	0	0	0	0
Electricity	3202.813	3828.329	4484.453	4802.631	4995.688	5109.494	5187.383	31610.79
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	73.61357	85.18003	99.77872	106.8582	111.1537	113.6859	115.4189	705.6889
	3514.192	3913.509	4584.231	4909.489	5106.841	5223.18	5302.802	32554.25

Since electricity is the only energy source for operating electrical appliances, the energy demand increases from 11728.66TJ to 15897.49TJ by 2030 and 18389.39TJ by 2050.

Table 4-6 Energy demand in urban sector for electrical appliances according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	11728.66	13571.51	15897.49	17025.44	17709.83	18113.27	18389.39	112435.6
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	11728.66	13571.51	15897.49	17025.44	17709.83	18113.27	18389.39	112435.6

In other end uses not included here, the overall use of firewood decreases from 12066.45TJ to 11279.55TJ by 2030. Similarly demand for all solid fuels such as agricultural waste, animal dung and coal are reduced to achieve the SDG target. The demand of electricity increases from 18 TJ to 7466TJ by 2050.

Table 4-7 Energy demand in urban sector for other end uses according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	12066.45	12036.54	11279.55	9059.887	6282.719	3212.922	0	53938.07
Agricultural Residue	472.2114	471.0406	441.4164	354.5516	245.8693	125.7352	0	2110.825
Animal Waste	1938.76	1933.953	1812.325	1455.684	1009.466	516.2315	0	8666.419
Coal	0.260611	0.259965	0.243616	0.195676	0.135694	0.069393	0	1.164955
Kerosene	11.58098	0	0	0	0	0	0	11.58098
LPG	3676.2	3675.487	3444.332	2766.534	1918.496	981.1006	0	16462.15
Electricity	18.77613	778.7382	2020.645	3351.1	4720.614	6091.09	7466.13	24447.09
Biogas	153.5192	153.1386	143.5075	115.2672	79.93382	40.87739	0	686.2437
Briquette	4.902099	4.889945	4.582412	3.680655	2.552407	1.305277	0	21.91279
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	18342.66	19054.05	19146.6	17106.9	14259.79	10969.33	7466.13	106345.5

ii. Rural Sector

The energy demand for cooking decreases rapidly due to shifting of population to urban areas. Due to rapid urbanization rural population decreases causing decrease in the overall energy demand.

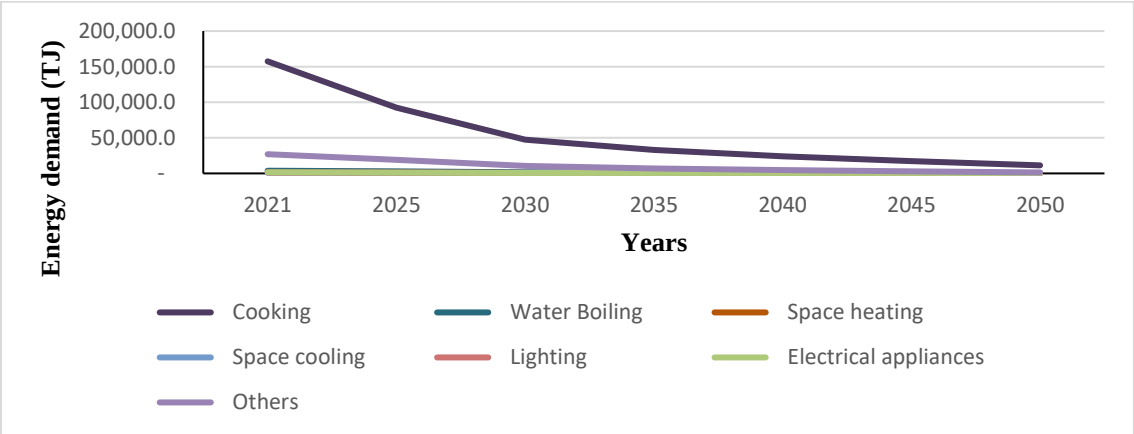


Figure 4-5 Sustainable Development Goals Rural Energy demand

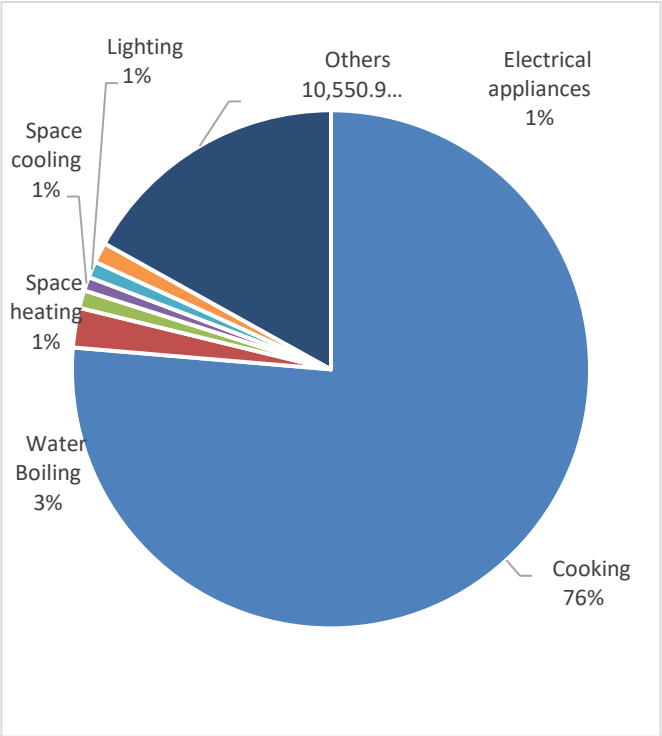


Figure 4-6 Rural electricity demand 2030 end use wise

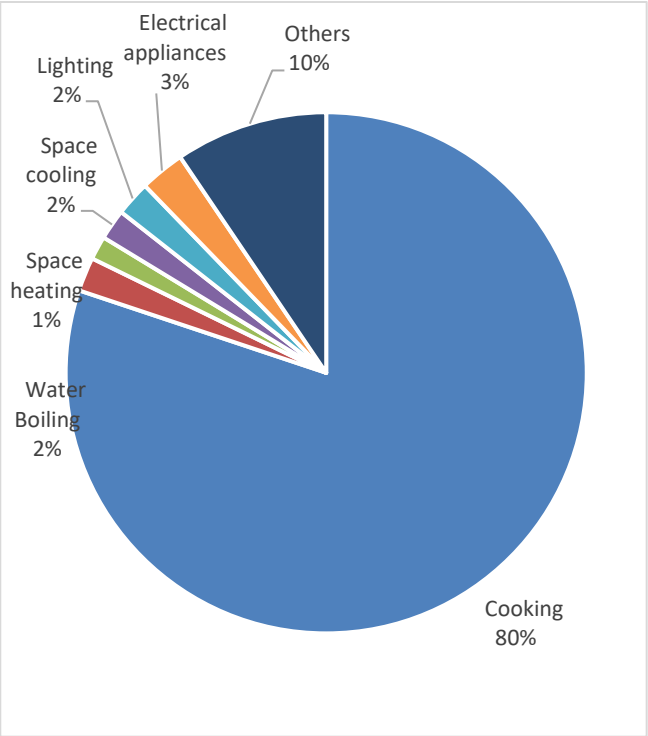


Figure 4-7 Rural electricity demand 2050 end use wise

The use of firewood for cooking decreases from 136373.9TJ to 28658.05TJ by 2030 due to the target of decreasing solid fuel and increasing the use of LPG and electricity for cooking. The energy consumption of other solid fuel also decreases. Since there is target of increasing LPG usage to 30%, the energy demand for LPG increases from 7089.75TJ to 8683.869TJ by 2050 and the demand of electricity increases from 160.3295TJ to 2636.327TJ by 2050.

Table 4-8 Energy demand in rural sector for cooking according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	136373.9	66870.41	28658.05	17245.58	9806.416	4215.157	0	263169.5
Agricultural Residue	6131.283	4232.955	2207.282	1328.278	755.3034	324.6571	0	14979.76
Animal Waste	3620.927	2499.839	1303.546	784.4356	446.0565	191.7314	0	8846.536
Coal	19.98431	13.7969	7.194416	4.329389	2.461836	1.058187	0	48.82503
Kerosene	10.41087	7.18752	3.747945	2.255404	1.282499	0.551265	0	25.4355
LPG	7089.75	12854.54	10211.64	9654.057	9480.282	9220.969	8683.869	67195.11
Electricity	160.3295	3179.047	3749.069	3321.371	3100.164	2894.832	2636.327	19041.14
Biogas	4036.698	2786.881	1453.224	874.5078	497.2746	213.7468	0	9862.332
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	157443.3	92444.66	47593.76	33214.81	24089.24	17062.7	11320.2	383168.6

The use of solid fuel for water boiling such as firewood, animal dung, agricultural wastes, coal decreases due to the target of decreasing solid fuel usage and also due to the rapid electrification strategies and also due to the shifting of population to urban areas, Similarly, the use of LPG, biogas is also going on decreasing trend. But due to electrification and increase in use of electric boilers the demand of electricity rises from 19TJ to 193.5TJ by 2030 and 298TJ by 2050.

Table 4-9 Energy demand in rural sector for water boiling according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	3439.538	2374.611	1238.245	745.1396	423.7115	182.1267	0	8403.372
Agricultural Residue	18.05072	12.46197	6.498317	3.910497	2.22364	0.955802	0	44.10095
Animal Waste	0.618145	0.426759	0.222534	0.133915	0.076148	0.032731	0	1.510233
Coal	1.801179	1.243509	0.64843	0.390206	0.221884	0.095374	0	4.400583
Kerosene	0	0	0	0	0	0	0	0
LPG	256.2212	176.8916	92.24045	55.5076	31.56349	13.56715	0	625.9915
Electricity	19.68358	140.7018	193.5072	236.9395	271.7641	293.5186	298.1888	1454.304
Biogas	22.7346	15.69566	8.184528	4.92521	2.80064	1.203818	0	55.54445
Briquette	0	0	0	0	0	0	0	0
Solar thermal	2.031312	1.40239	0.731279	0.440062	0.250234	0.10756	0	4.962837
Solar PV	0	0	0	0	0	0	0	0
	3760.679	2723.434	1540.278	1047.387	732.6116	491.6078	298.1888	10594.19

Similarly, for heating purpose the use of firewood is to be reduced to meet the target and hence the demand of firewood decreases from 1535.86TJ to 552.9TJ by 2030. The increasing use of electric heaters causes increase in electricity demand i.e. from 28TJ TO 206TJ by 2050.

Table 4-10 Energy demand in rural sector for space heating according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	1535.862	1060.338	552.9151	332.7282	189.2004	81.32528	0	3752.369
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	28.03512	107.2789	139.0404	167.0153	189.7559	203.7907	206.2575	1041.174
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	1563.897	1167.617	691.9555	499.7434	378.9563	285.116	206.2575	4793.542

As only electricity is used for space cooling according to SDG the demand for electricity decreases from 1030.565TJ to 537.959TJ by 2030 and 267.04TJ by 2050. This decline in energy demand is due to shifting of rural population to urban areas. Since the population using energy decreases and hence the electricity demand also decreases.

Since the rural population is decreasing rapidly due to urban migration, the requirement of electricity also reduces from 1515.6TJ to 791.16TJ by 2030 and 392.74TJ by 2050.

In other end uses the consumption of solid fuel, LPG, biogas decreases rapidly due to shifting of population and the demand of electricity increases a bit from 9TJ to 1337TJ by 2050.

The use of kerosene for lighting is substantially reduced and hence the energy demand for kerosene decreases from 144.43TJ to 0 by 2030. Similarly, the demand of electricity also decreases from 948.15TJ to 310.69TJ by 2050. This decrease in demand is due to rapid shifting of rural population to urban areas. Similarly, the use of solar lights also decreases due to less population in rural sector and hence demand from solar source decreases from 150.5TJ to 4.619TJ by 2050.

Table 4-11 Energy demand in rural sector for space cooling according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	1030.565	825.3259	537.9596	431.6378	368.1657	316.5022	267.0487	3777.204
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	1030.565	825.3259	537.9596	431.6378	368.1657	316.5022	267.0487	3777.204

Table 4-12 Energy demand in rural sector for lighting according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	144.4334	0	0	0	0	0	0	144.4334
LPG	0	0	0	0	0	0	0	0
Electricity	948.1529	827.5164	553.0602	454.7244	397.2148	349.5192	301.6941	3831.882
Biogas	61.98381	42.79278	22.31437	13.42814	7.635691	3.2821	0	151.4369
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	150.5438	105.9027	57.08446	36.21854	22.71812	12.50275	4.619825	389.5902

Table 4-13 Energy demand in rural sector for electrical appliances according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	1515.622	1213.783	791.1616	634.7972	541.4506	465.4706	392.7409	5555.026
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	1515.622	1213.783	791.1616	634.7972	541.4506	465.4706	392.7409	5555.026

Table 4-14 Energy demand in rural sector for remaining end uses according to SDG

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	24544.77	16945.38	8836.196	5317.364	3023.633	1299.668	0	59967
Agricultural Residue	434.3586	299.8753	156.3705	94.0992	53.50797	22.99969	0	1061.211
Animal Waste	408.3814	281.941	147.0186	88.47152	50.30789	21.62417	0	997.7446
Coal	0.870727	0	0	0	0	0	0	0.870727
Kerosene	14.68261	0	0	0	0	0	0	14.68261
LPG	1194.619	824.7485	430.0666	258.8015	147.1633	63.25616	0	2918.655
Electricity	9.152268	576.4773	839.48	1045.64	1209.24	1312.377	1337.516	6329.882
Biogas	345.6454	247.9732	129.3061	77.81261	44.24687	19.01893	0	864.0031
Briquette	34.65566	23.9258	12.47615	7.507781	4.269177	1.835049	0	84.66961
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	26987.13	19200.32	10550.91	6889.697	4532.367	2740.779	1337.516	72238.72

a. Fuel wise SDG scenario

As the use of solid fuel is to be reduced substantially, we can see that the use of firewood goes highly on decreasing trend and reaches 0TJ by 2050. Similarly, the demand of electricity and LPG goes on continuous increment due to target of electrification and increasing the use of LPG for lighting and heating purpose.

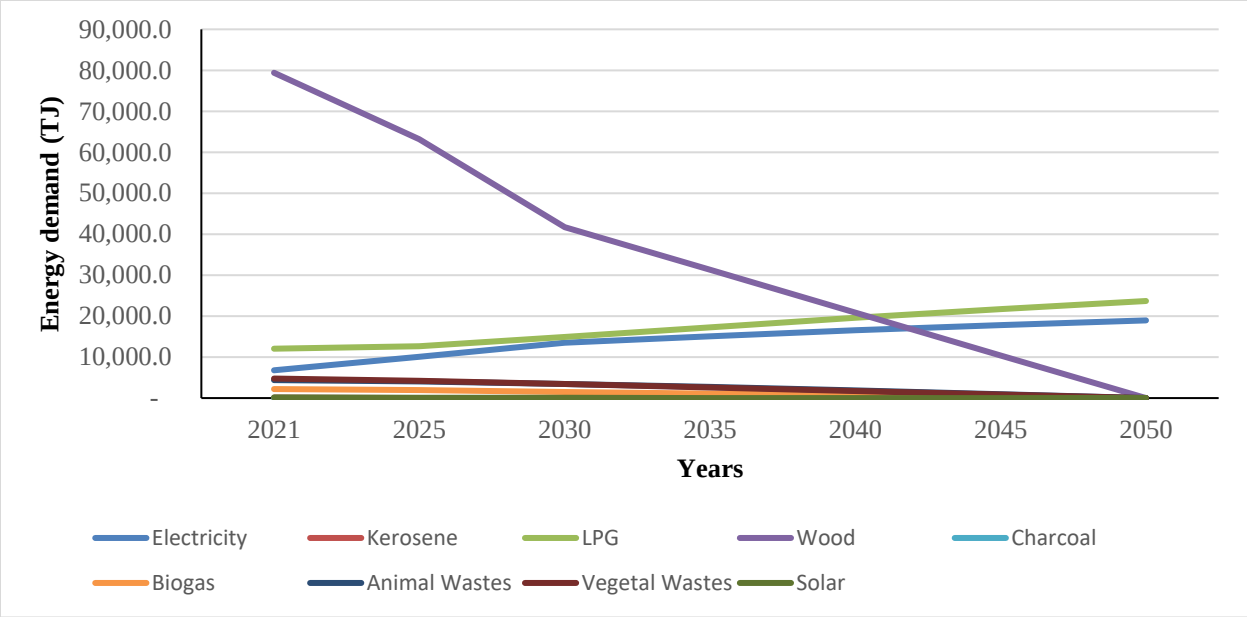


Figure 4-8 Fuel wise overall demand according to Sustainable Development Goals

Here we can see that by 2030 the use of wood is decreases to 53% of total energy usage and decreases to 0% by 2050 to meet the SDG target and the electricity consumption increases to 17% of total energy usage by 2030. Similarly, the use of electricity and LPG increases highly to reach 44% and 56% respectively by 2050 which accounts for all the energy use by 2050.

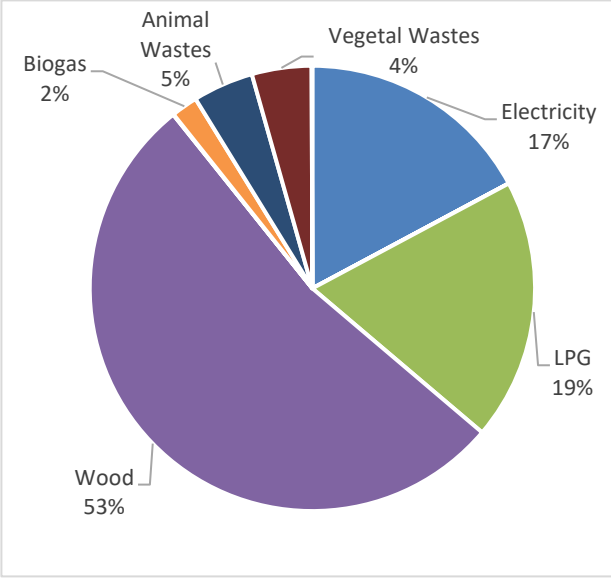


Figure 4-9 Fuel wise electricity demand 2030 SDG

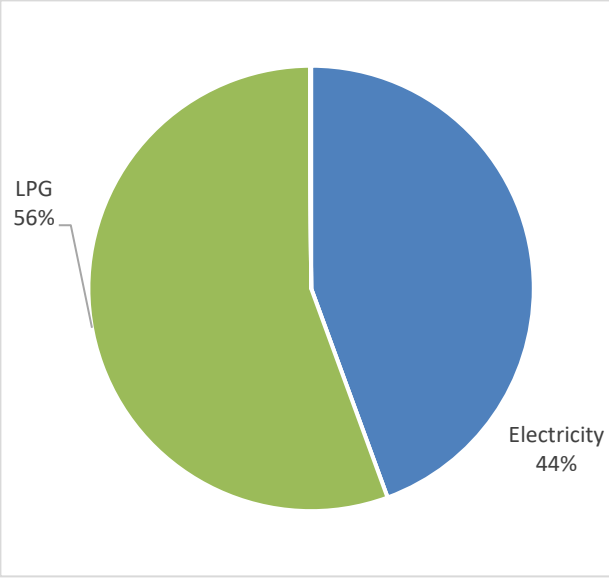


Figure 4-10 Fuel wise electricity demand 2050 SDG

4.1.3 Second Nationally Determined Contribution (NDC) scenario

a. End-use wise demand

i. Urban sector

Here we can see that the demand for cooking decreases substantially to 76% of total energy usage by 2030 and 63% by 2050. Hence the consumption of electricity increases to overcome the demand. The target of NDC is to ensure 25% of households use electric stoves as their primary mode of cooking by 2030 and by 2025, install 500,000 improved cookstoves, specifically in rural areas. Also, it targets to install an additional 200,000 household biogas plants and 500 large scale biogas plants by 2025. So, the use of electric appliances increases consuming 7% of total end use usage and increases to 16% by 2050.

According to NDC the demand for cooking decreases here due to decrease in use of firewood and other solid fuels for cooking purpose and rather shifting to electrified methods for other end uses too. The demand of electricity continuously goes on increasing trend due to increase in use of electrified cookstoves and improve cookstoves which uses very less energy compared to solid fuels used previously.

Table 4-15 Energy demand in urban sector for cooking according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	102683.2	102428.6	95986.81	77097.91	53464.74	27341.36	0	459002.7
Agricultural Residue	9995.655	9970.873	9343.796	7505.063	5204.502	2661.533	0	44681.42
Animal Waste	9838.752	9814.359	9197.125	7387.255	5122.806	2619.754	0	43980.05
Coal	45.71335	45.60002	42.73219	34.32307	23.80187	12.17205	0	204.3425
Kerosene	14.08447	14.04955	13.16596	10.57507	7.333449	3.750256	0	62.95875
LPG	30173.21	32692.65	35042.93	32892.78	29392.13	25128.96	20504.08	205826.7
Electricity	1071.259	5592.775	12925.39	21270.34	29851.82	38434.34	47043.17	156189.1
Biogas	3274.431	3788.922	4438.292	4753.195	4944.265	5056.9	5133.986	31389.99
Briquette	19.91522	19.86584	18.61646	14.95299	10.36938	5.302805	0	89.0227
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	157116.2	164367.7	167008.9	150966.4	128021.8	101264.1	72681.24	941426.3

Here we can see that the use of firewood decreases from 102683.2TJ to 95986 TJ by 2030. This decrease in demand is due to the target of shifting into electric cookstoves and improved cookstoves using LPG. Due to increase in use of electric cookstoves in urban areas the demand of electricity increases from 1071.259TJ to 12925TJ by 2030 and increases rapidly to 47043.17TJ by 2050. The use of LPG decreases slightly due to electrification strategy. Since the number of biogas plants is to be increased substantially the demand for biogas energy increases from 3274.431TJ to 5133.986TJ by 2050.

The use of solid fuels has been decreasing substantially due to electrification. So, the use of firewood, agricultural residue and biogas decreases. The demand of LPG rises by a small amount due to increase in population shifting to urban areas and due to increase in usage of electric boilers for water boiling the demand for electricity increases from 146.06TJ to 650TJ by 2030 and increases rapidly to 2366.96TJ BY 2050.

Table 4-16 Energy demand in urban sector for water boiling according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	2884.902	1854.55	0	0	0	0	0	4739.452
Agricultural Residue	101.7877	65.43385	0	0	0	0	0	167.2215
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	996.9852	1658.251	2681.328	2396.89	1999.477	1540.016	1050.782	12323.73
Electricity	146.0689	340.6497	650.3386	1070.213	1501.989	1933.817	2366.968	8010.043
Biogas	31.31277	31.23513	29.27073	23.51065	16.30382	8.337618	0	139.9707
Briquette	0.079149	0.078953	0.073988	0.059428	0.041211	0.021075	0	0.353803
Solar thermal	382.2483	381.3006	357.3202	287.0044	199.0277	101.7809	0	1708.682
Solar PV	0	0	0	0	0	0	0	0
	4543.384	4331.499	3718.331	3777.677	3716.839	3583.972	3417.75	27089.45

The use of firewood LPG and briquettes decreases due to the rapid electrification strategies hence increasing the use of electric heaters and hence increasing the demand of electricity from 473.8436TJ to 1137.3TJ by 2030 and increases rapidly to 2588.146TJ by 2050.

Since electricity is only the energy source used for space cooling, due to rapid increase in population hence increase the number of air conditioners increasing the demand of electricity from 4063.407TJ to 5507.7TJ by 2030 and 6371TJ by 2050.

Table 4-17 Energy demand in urban sector for space heating according to NDC

End use/ year	**2021**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**Total**
Firewood	2305.309	2299.593	2154.969	1730.901	1200.32	613.8321	0	10304.92
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	20.21142	28.9786	27.15611	21.81215	15.12597	7.735279	0	121.0195
Electricity	473.8436	736.127	1137.318	1512.555	1879.739	2235.923	2588.146	10563.65
Biogas	0	0	0	0	0	0	0	0
Briquette	12.05347	0	0	0	0	0	0	12.05347
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	2811.417	3064.699	3319.443	3265.267	3095.185	2857.491	2588.146	21001.65

Table 4-18 Energy demand in urban sector for space cooling according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	4063.407	4701.866	5507.702	5898.481	6135.589	6275.364	6371.025	38953.44
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	4063.407	4701.866	5507.702	5898.481	6135.589	6275.364	6371.025	38953.44

Table 4-19 Energy demand in urban sector for lighting according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	237.766	237.17	222.26	178.52	123.79	63.30	0	1062.83
LPG	0	0	0	0	0	0	0	0
Electricity	3202.81	3722.91	4385.67	4723.28	4940.66	5081.35	5187.38	31244.09
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	73.61	85.18	99.7787	106.858	111.153	113.685	115.418	705.6889
	3514.192	4045.274	4707.709	5008.668	5175.619	5258.352	5302.802	33012.62

The use of kerosene for lighting purposes decreased substantially since the use of renewable solid fuels is to be reduced and electrification in lighting saves much more energy than using kerosene for lighting purposes. The use of electricity increases from 3202.8TJ to 4385.67TJ by 2030 and increases to 5187.3TJ by 2050. The solar lighting number is also increasing hence the demand of solar lighting increases from 73.6TJ to 116.4TJ by 2050.

Since electricity is the sole source contributing energy to electrical appliances. So due to the increase in urban population the demand of electricity rises from 11728.6TJ to 18389.39TJ by 2050.

Table 4-20 Energy demand in urban sector for electrical appliances according to NDC

End use/ year	**2021**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**Total**
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	11728.66	13571.51	15897.49	17025.44	17709.83	18113.27	18389.39	112435.6
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	11728.66	13571.51	15897.49	17025.44	17709.83	18113.27	18389.39	112435.6

In other end uses the use of solid fuels, LPG, biogas decreases and the demand for electricity rises rapidly from 18TJ to 7466TJ by 2050.

Table 4-21 Energy demand in urban sector for remaining end uses according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	12066.45	12036.54	11279.55	9059.887	6282.719	3212.922	0	53938.07
Agricultural Residue	472.2114	471.0406	441.4164	354.5516	245.8693	125.7352	0	2110.825
Animal Waste	1938.76	1964.759	1841.193	1478.872	1025.546	524.4546	0	8773.585
Coal	0.260611	0.259965	0.243616	0.195676	0.135694	0.069393	0	1.164955
Kerosene	11.58098	0	0	0	0	0	0	11.58098
LPG	3676.2	3667.085	3436.459	2760.21	1914.111	978.8579	0	16432.92
Electricity	18.77613	778.7382	2020.645	3351.1	4720.614	6091.09	7466.13	24447.09
Biogas	153.5192	153.1386	143.5075	115.2672	79.93382	40.87739	0	686.2437
Briquette	4.902099	4.889945	4.582412	3.680655	2.552407	1.305277	0	21.91279
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	18342.66	19076.45	19167.6	17123.76	14271.48	10975.31	7466.13	106423.4

ii. Rural sector

In the rural sector, due to increase in population and rapid electrification strategies the energy usage for cooking is reduced substantially. Since the use of electric cookstoves and improved cookstoves decreases the total, energy consumption which is very high while using firewood and other solid fuels. Hence final energy demand in all sectors decreases due to urban migration.

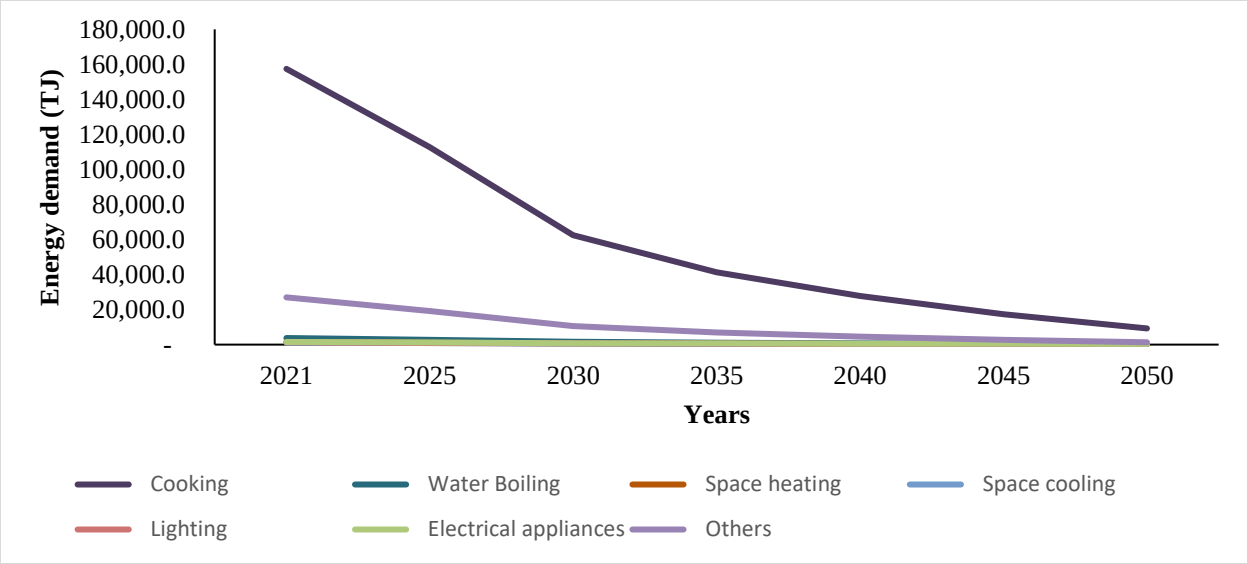


Figure 4-11 Second Nationally Determined Commissions Rural Energy demand

Here we can see the total energy usage for cooking is reduced to 81% by 2030 and to 76% by 2050. This is due to the rapid electrification which reduces the energy used for cooking in comparison to previously used solid fuel cooking techniques. Similarly, the use of electric appliances also goes on increasing trend using 1% of total energy consumption in 2030 increasing to 3% by 2050.

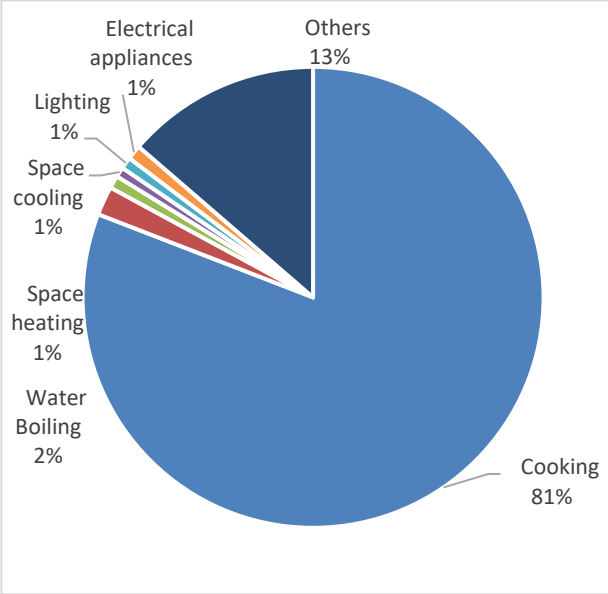


Figure 4-12 Rural energy demand 2030 end use wise NDC

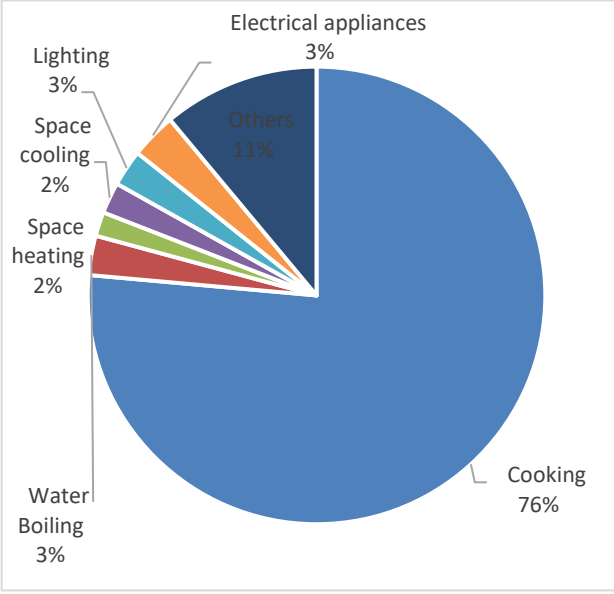


Figure 4-13 Rural energy demand 2050 end use wise NDC

The use of firewood and solid fuels are decreased due to target of increasing the number of electric and improved cookstoves. Here we can see that the demand of LPG and biogas also goes on decreasing trend due to rapid shifting of population to urban areas and few populations remaining to use the energy source. Although, there is decrease in the population, the demand for electricity rises due to increase in use of electric cookstoves. The electricity demand increases from 160TJ to 4000.286TJ by 2030 and increases to 6349TJ by 2050.

Table 4-22 Energy demand in rural sector for cooking according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	136373.9	94150.69	49095.04	29543.96	16799.69	7221.123	0	333184.4
Agricultural Residue	6131.283	4232.955	2207.282	1328.278	755.3034	324.6571	0	14979.76
Animal Waste	3620.927	2499.839	1303.546	784.4356	446.0565	191.7314	0	8846.536
Coal	19.98431	13.7969	7.194416	4.329389	2.461836	1.058187	0	48.82503
Kerosene	10.41087	0	0	0	0	0	0	10.41087
LPG	7089.75	5699.083	3741.952	2995.508	2549.144	2186.38	1840.497	26102.31
Electricity	160.3295	2798.956	4000.286	4973.069	5745.87	6232.596	6349.742	30260.85
Biogas	4036.698	3258.828	2124.152	1704.337	1453.715	1249.72	1054.451	14881.9
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	157443.3	112654.1	62479.46	41333.92	27752.24	17407.27	9244.69	428315

The use of solid fuels, LPG, biogas is decreases due to rapid electrification strategies and shifting of population. The increase in use of electric boilers for water boiling increases the demand of electricity from 19TJ to 150.17TJ by 2030 and 238.37TJ by 2050.

Table 4-23 Energy demand in rural sector for water boiling according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	3439.538	2374.611	1238.245	745.1396	423.7115	182.1267	0	8403.372
Agricultural Residue	18.05072	12.46197	6.498317	3.910497	2.22364	0.955802	0	44.10095
Animal Waste	0.618145	0.426759	0.222534	0.133915	0.076148	0.032731	0	1.510233
Coal	1.801179	1.243509	0.64843	0.390206	0.221884	0.095374	0	4.400583
Kerosene	0	0	0	0	0	0	0	0
LPG	256.2212	225.243	163.1518	137.7322	123.3006	111.0032	97.88183	1114.534
Electricity	19.68358	111.1537	150.1725	186.6912	215.7025	233.9744	238.3721	1155.75
Biogas	22.7346	15.69566	8.184528	4.92521	2.80064	1.203818	0	55.54445
Briquette	0	0	0	0	0	0	0	0
Solar thermal	2.031312	1.40239	0.731279	0.440062	0.250234	0.10756	0	4.962837
Solar PV	0	0	0	0	0	0	0	0
	3760.679	2742.238	1567.854	1079.363	768.2872	529.4996	336.2539	10784.17

The use of firewood is decreased substantially for space heating from 1535.8TJ to 552.9TJ by 2030. Similarly, due to the increase in electric heaters and air conditioners, the electricity demand for heating rises from 28TJ to 206TJ by 2050.

Electricity is only the source used for using fans, coolers and air conditioners. But the demand for electricity in space cooling decreases from 1030.5TJ to 206.25TJ by 2050. This is due to the rapid shift of population to urban areas.

Table 4-24 Energy demand in rural sector for space heating according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	1535.862	1060.338	552.9151	332.7282	189.2004	81.32528	0	3752.369
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	28.03512	107.2789	139.0404	167.0153	189.7559	203.7907	206.2575	1041.174
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	1563.897	1167.617	691.9555	499.7434	378.9563	285.116	206.2575	4793.542

Table 4-25 Energy demand in rural sector for space cooling according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	1030.565	825.3259	537.9596	431.6378	368.1657	316.5022	267.0487	3777.204
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	1030.565	825.3259	537.9596	431.6378	368.1657	316.5022	267.0487	3777.204

The use of kerosene and biogas for lighting is decreased substantially due to increase in use of electric bulbs for lighting discouraging the use of solid fuels. Although there is electrification, the demand for rural lighting decreases from 948TJ to 290TJ by 2050 due to rapid shifting of population to urban areas.

Table 4-26 Energy demand in rural sector for lighting according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	144.4334	0	0	0	0	0	0	144.4334
LPG	0	0	0	0	0	0	0	0
Electricity	948.1529	822.9186	546.3172	446.3084	387.4726	338.9401	290.9084	3781.018
Biogas	61.98381	49.68941	32.42885	26.05219	22.24898	19.15072	16.17855	227.7325
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	150.5438	105.9027	57.08446	36.21854	22.71812	12.50275	4.619825	389.5902
	1305.114	978.5107	635.8305	508.5791	432.4397	370.5936	311.7068	4542.774

Due to continuous shifting of rural population to urban areas, the demand of electricity for operating electrical appliances decreases from 1515.6TJ to 392.7TJ by 2050.

Table 4-27 Energy demand in rural sector for electrical appliances according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	1515.622	1213.783	791.1616	634.7972	541.4506	465.4706	392.7409	5555.026
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	1515.622	1213.783	791.1616	634.7972	541.4506	465.4706	392.7409	5555.026

For using other end uses, the use of other fuels except electricity decreases rapidly due to rapid electrification strategies increasing the electricity demand from 9.15TJ to 1337.5TJ by 2050.

Table 4-28 Energy demand in rural sector for remaining end uses according to NDC

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	24544.77	16945.38	8836.196	5317.364	3023.633	1299.668	0	59967
Agricultural Residue	434.3586	299.8753	156.3705	94.0992	53.50797	22.99969	0	1061.211
Animal Waste	408.3814	281.941	147.0186	88.47152	50.30789	21.62417	0	997.7446
Coal	0.870727	0	0	0	0	0	0	0.870727
Kerosene	14.68261	0	0	0	0	0	0	14.68261
LPG	1194.619	832.3939	434.0533	261.2006	148.5274	63.84254	0	2934.637
Electricity	9.152268	576.4773	839.48	1045.64	1209.24	1312.377	1337.516	6329.882
Biogas	345.6454	238.6289	124.4335	74.88041	42.57952	18.30224	0	844.4699
Briquette	34.65566	23.9258	12.47615	7.507781	4.269177	1.835049	0	84.66961
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	26987.13	19198.62	10550.03	6889.164	4532.064	2740.649	1337.516	72235.17

b. Fuel-wise NDC scenario

We can see that the use of firewood decreases rapidly due to the NDC's target of increasing the use of electric and improved cookstoves reducing the use of solid fuel. This electrification increases the demand for electricity hence reducing the demand for other fuels due to rapid electrification strategies.

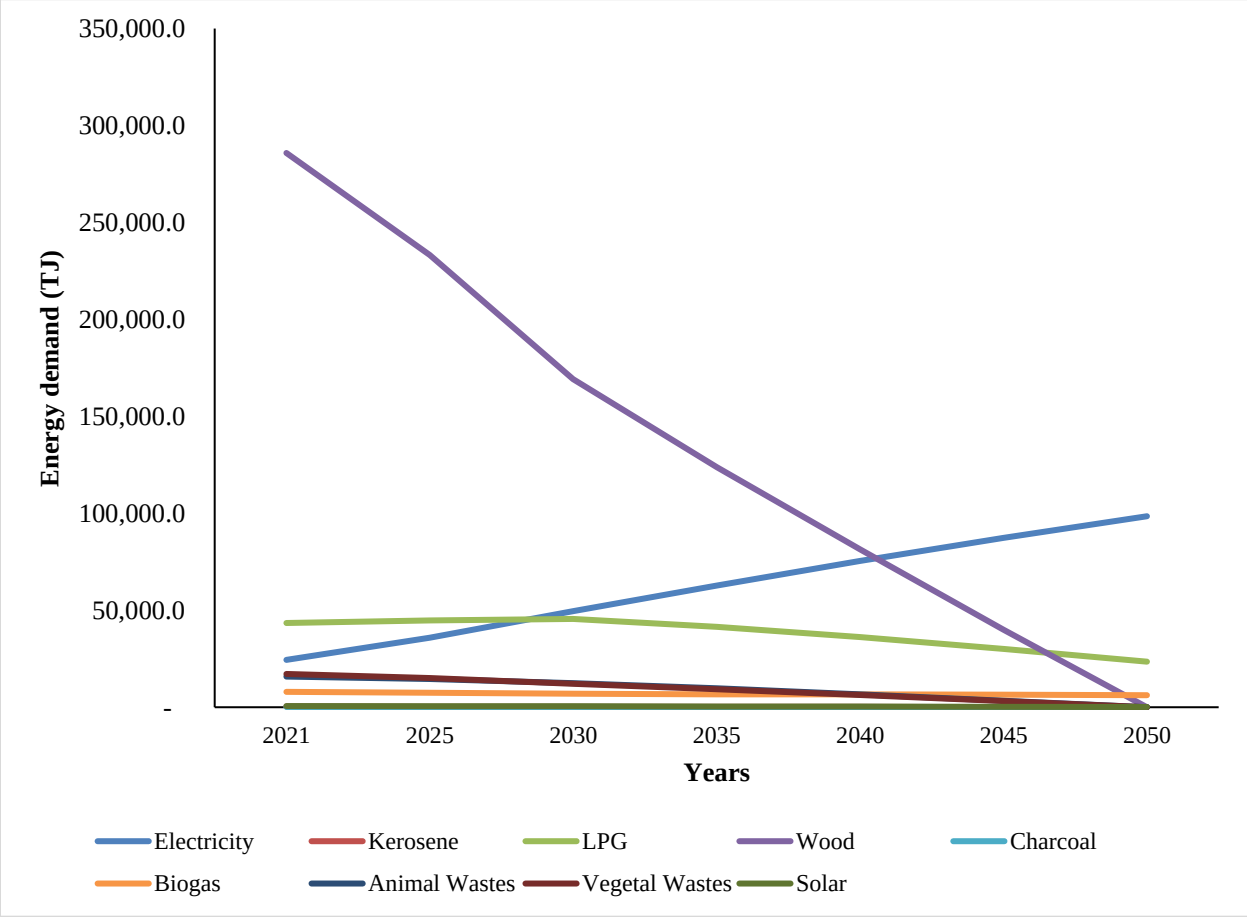


Figure 4-14 Fuel wise overall demand according to Second Nationally Determined Commission (NDC)

We can see that the use of wood is decrease to 57% of total energy usage by 2030 and is targeted to decrease to 0% by 2050. Due to the decrease in use of solid fuels, the consumption of electricity increases by a substantial amount increasing by 17% in 2030 to 77% of total energy usage by 2050. The use of LPG and biogas is also increased due to NDC's target of increasing the volume of improved and electric cookstoves and biogas plants by 2030.

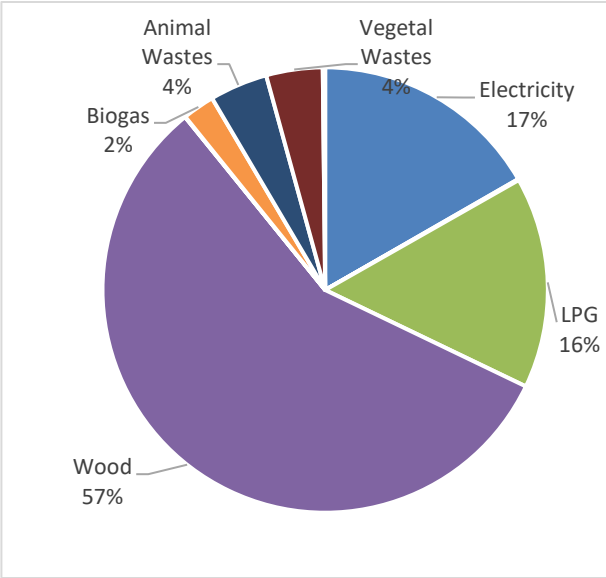


Figure 4-15 Fuel wise energy demand 2030 NDC

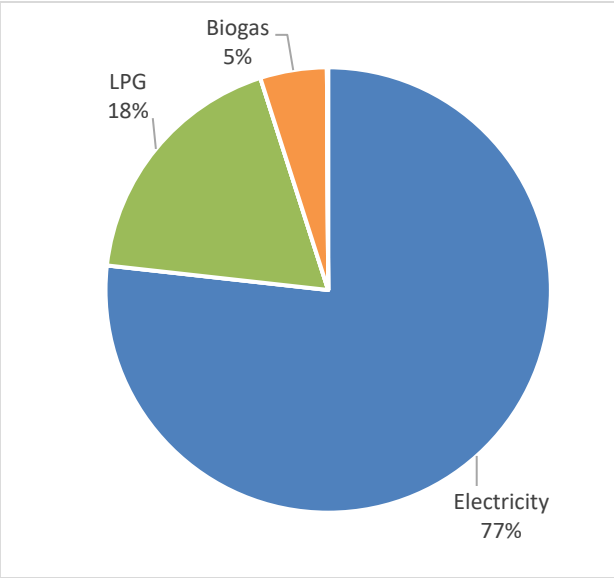


Figure 4-16 Fuel wise energy demand 2050 NDC

4.1.4 Nepal's long-term strategy for net zero emission (LTS) scenario

LTS targets to achieve per capita GDP growth of at least seven percent by 2030 and acquire 100% electrification in different end uses of residential sector.

a. End-use wise demand

i. Urban sector

In the urban sector, due to rapid electrification, the use of solid fuel decreases which decreases the total energy due to energy efficient modern technologies in cooking sector. In other sectors the demand rises in very small rate.

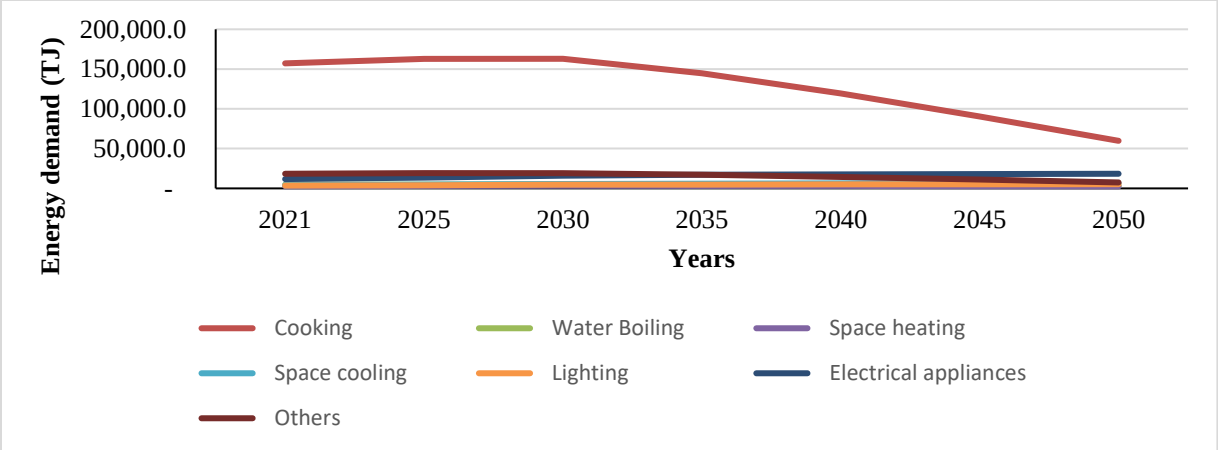


Figure 4-17 LTS Urban energy demands

Here we can see the total energy consumed by cooking decreases due to the increase in use of energy efficient technologies. Similarly, the use of electric appliances increases increasing the urban energy demand in electricity.

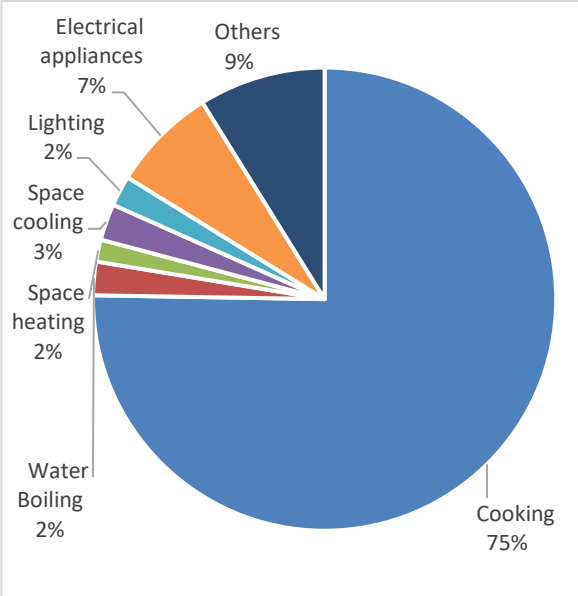


Figure 4-18 Urban energy demand 2030 end use wise

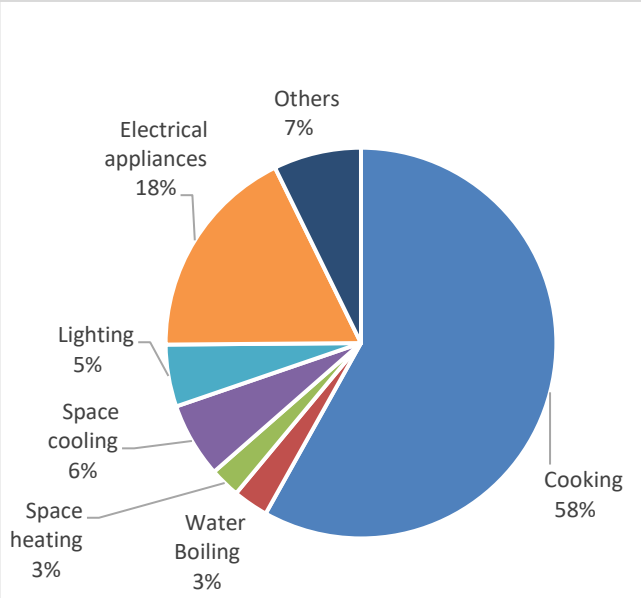


Figure 4-19 Urban energy demand 2050 end use wise

We can see that the use of firewood for cooking is reduced substantially from 102683TJ to 95986TJ by 2030 due to use of energy efficient technologies for cooking purpose. Similarly, the use of firewood reaches 0TJ by 2030 due to the target of 100% electrification by 2050. The demand of electricity increases rapidly from 1071TJ to 59805TJ by 2050 due to increasing electrification and increasing of urban population

Table 4-29 Energy demand in urban sector for cooking according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	102683.2	102428.6	95986.81	77097.91	53464.74	27341.36	0	459002.7
Agricultural Residue	9995.655	9970.873	9343.796	7505.063	5204.502	2661.533	0	44681.42
Animal Waste	9838.752	9814.359	9197.125	7387.255	5122.806	2619.754	0	43980.05
Coal	45.71335	45.60002	42.73219	34.32307	23.80187	12.17205	0	204.3425
Kerosene	14.08447	14.04955	13.16596	10.57507	7.333449	3.750256	0	62.95875
LPG	30173.21	30098.4	28205.48	22655.02	15710.48	8034.188	0	134876.8
Electricity	1071.259	7156.476	17046.71	27534.62	38292.85	49036.46	59805.71	199944.1
Biogas	3274.431	3266.312	3060.891	2458.549	1704.919	871.8792	0	14636.98
Briquette	19.91522	19.86584	18.61646	14.95299	10.36938	5.302805	0	89.0227
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	157116.2	162814.6	162915.3	144698.3	119541.8	90586.4	59805.71	897478.3

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The use of solid fuels, LPG, biogas for heating purpose decreases substantially increasing the use of electric water boilers for heating causing the rise of electricity demand from 146TJ to 3009TJ by 2050.

Table 4-30 Energy demand in urban sector for water boiling according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	2884.902	2877.75	2696.765	2166.079	1502.101	768.16	0	12895.76
Agricultural Residue	101.7877	101.5353	95.14964	76.42548	52.99843	27.10289	0	454.9994
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	996.9852	994.5133	931.9675	748.5689	519.1067	265.4662	0	4456.608
Electricity	146.0689	452.0169	943.86	1454.602	1974.688	2491.802	3009.112	10472.15
Biogas	31.31277	31.23513	29.27073	23.51065	16.30382	8.337618	0	139.9707
Briquette	0.079149	0.078953	0.073988	0.059428	0.041211	0.021075	0	0.353803
Solar thermal	382.2483	381.3006	357.3202	287.0044	199.0277	101.7809	0	1708.682
Solar PV	0	0	0	0	0	0	0	0
	4543.384	4838.43	5054.408	4756.25	4264.266	3662.67	3009.112	30128.52

The use of solid fuels, LPG and briquettes is decreased for heating purposes rising the number of electric heaters which increases the demand of electricity from 473.8TJ to 2588TJ by 2050.

Table 4-31 Energy demand in urban sector for space heating according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	2305.309	2299.593	2154.969	1730.901	1200.32	613.8321	0	10304.92
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	20.21142	20.1613	18.89334	15.17539	10.52361	5.381673	0	90.34673
Electricity	473.8436	736.127	1137.318	1512.555	1879.739	2235.923	2588.146	10563.65
Biogas	0	0	0	0	0	0	0	0
Briquette	12.05347	12.02358	11.26741	9.050134	6.275956	3.209464	0	53.88001
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	2811.417	3067.905	3322.448	3267.681	3096.858	2858.347	2588.146	21012.8

Since only electricity is used in fans, coolers and air conditioners, the demand of electricity for space cooling rises from 4063TJ to 6371TJ by 2050.

Table 4-32 Energy demand in urban sector for space cooling according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	4063.407	4701.866	5507.702	5898.481	6135.589	6275.364	6371.025	38953.44
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	4063.407	4701.866	5507.702	5898.481	6135.589	6275.364	6371.025	38953.44

The use of kerosene in lighting is reduced to 0. Due to electrification and increase in number of electric bulbs the demand for electricity rises from 3202TJ to 5283TJ by 2050. The use of solar lighting is also seen in increasing trend which increases the energy demand from 73TJ to 187TJ by 2030 and decreasing to 0 by 2050 due to 100% electrification target by LTS.

Since electricity is only the source of energy for operating electrical appliances. So the electricity demand increases from 11728TJ to 18389TJ by 2050.

Table 4-33 Energy demand in urban sector for lighting according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	237.766	0	0	0	0	0	0	237.766
LPG	0	0	0	0	0	0	0	0
Electricity	3202.813	3732.708	4411.475	4766.276	5001.353	5159.761	5283.565	31557.95
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	73.61357	199.9252	187.3517	150.4834	104.3551	53.36618	0	769.0951
	3514.192	3932.633	4598.827	4916.76	5105.708	5213.127	5283.565	32564.81

Table 4-34 Energy demand in urban sector for electrical appliances according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	11728.66	13571.51	15897.49	17025.44	17709.83	18113.27	18389.39	112435.6
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	11728.66	13571.51	15897.49	17025.44	17709.83	18113.27	18389.39	112435.6

The use of solid fuels, biogas, LPG is reduced which increases the electricity demand in other end uses increasing the demand from 18TJ to 2020.6TJ by 2030 and 7466TJ by 2050.

Table 4-35 Energy demand in urban sector for remaining end uses according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	12066.45	12036.54	11279.55	9059.887	6282.719	3212.922	0	53938.07
Agricultural Residue	472.2114	471.0406	441.4164	354.5516	245.8693	125.7352	0	2110.825
Animal Waste	1938.76	1933.953	1812.325	1455.684	1009.466	516.2315	0	8666.419
Coal	0.260611	0.259965	0.243616	0.195676	0.135694	0.069393	0	1.164955
Kerosene	11.58098	11.55226	10.82573	8.695374	6.029941	3.083655	0	51.76794
LPG	3676.2	3667.085	3436.459	2760.21	1914.111	978.8579	0	16432.92
Electricity	18.77613	778.7382	2020.645	3351.1	4720.614	6091.09	7466.13	24447.09
Biogas	153.5192	153.1386	143.5075	115.2672	79.93382	40.87739	0	686.2437
Briquette	4.902099	4.889945	4.582412	3.680655	2.552407	1.305277	0	21.91279
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	18342.66	19057.2	19149.55	17109.27	14261.43	10970.17	7466.13	106356.4

ii. Rural sector

In the rural sector, due to shifting to urban areas and use of energy efficient technologies the energy use for cooking is decreased rapidly to 2030 and slightly to 2050. Similarly other sources of energy use is also reduced due to very less population in urban areas.

We can see that the energy used for cooking is reduced to 80% by 2030 and to 74% by 2050. This is due to the use of energy efficient technologies in cooking. Similarly, the use of electric appliances is increased to 1% by 2030 and to 4% by 2050. Electricity will only be the source used since the LTS targets 100% electrification by 2050.

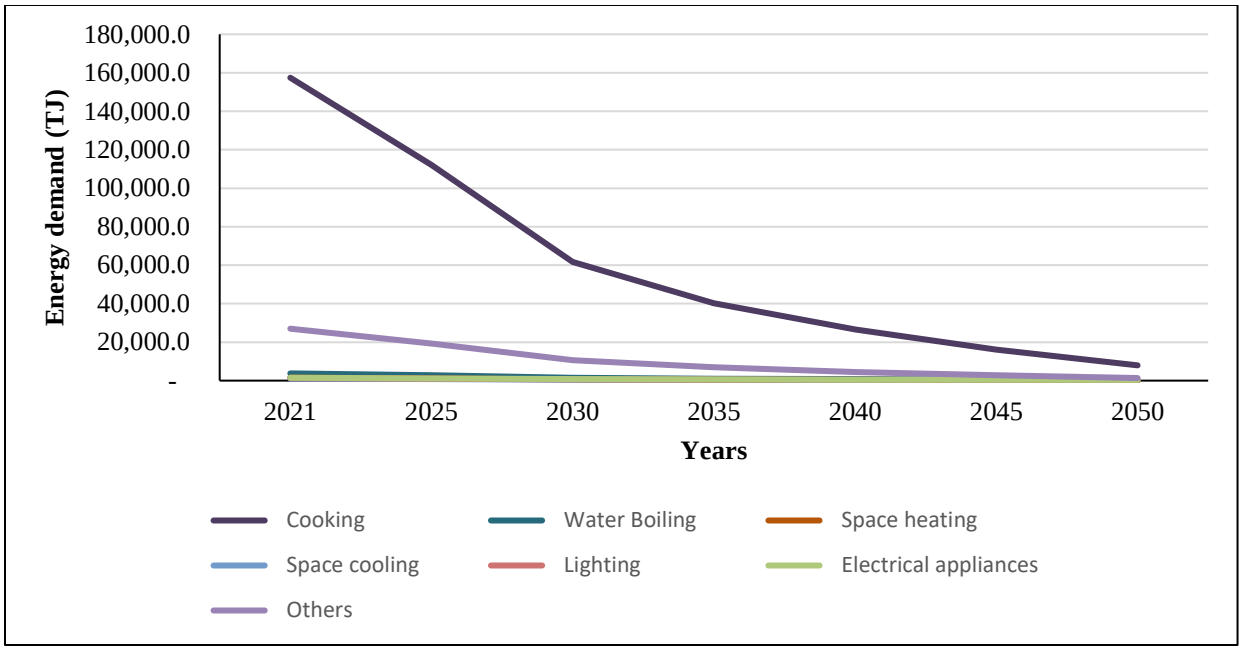


Figure 4-20 LTS Rural energy demand

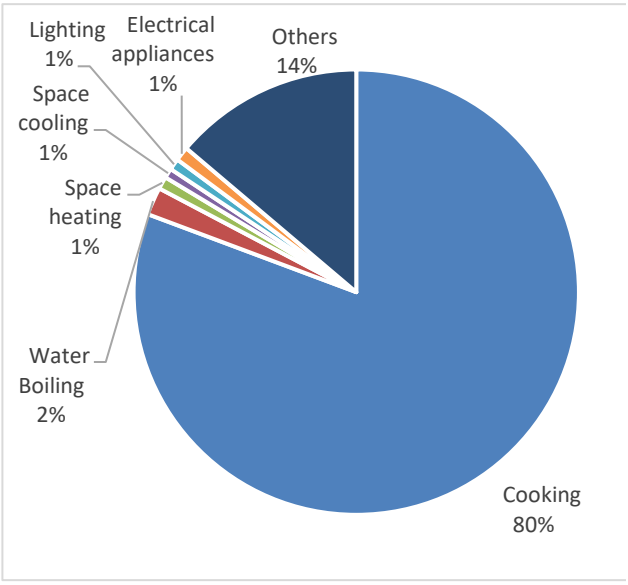


Figure 4-21 Rural energy demand 2030 end use wise

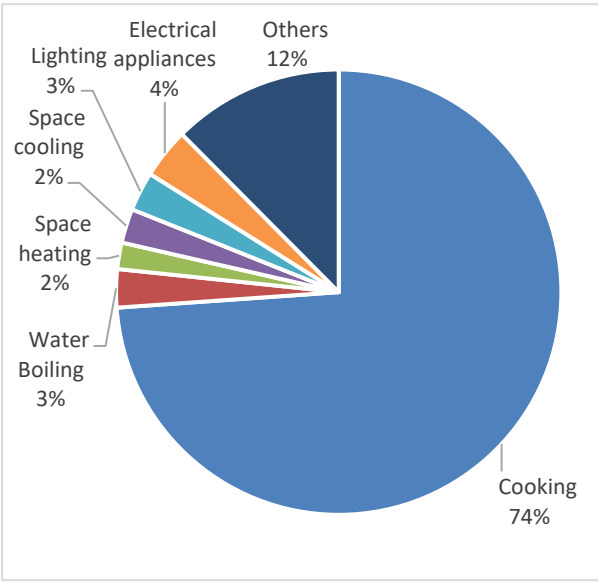


Figure 4-22 Rural energy demand 2050 end use wise

The use of firewood is substantially decreased from 136373TJ to 49095TJ by 2030 and 0TJ by 2050 since the target is to achieve 100% electrification. Although the population decreases, shifting to electric efficient technologies increases the electricity consumption increasing the demand from 160TJ to 5023.5TJ by 2030 and 7943.135TJ by 2050. Similarly, the use of other fuel sources decreases to 2030 and reaches 0 by 2050 due to 100% electrification target by LTS.

Table 4-36 Energy demand in rural sector for cooking according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	136373.9	94150.69	49095.04	29543.96	16799.69	7221.123	0	333184.4
Agricultural Residue	6131.283	4232.955	2207.282	1328.278	755.3034	324.6571	0	14979.76
Animal Waste	3620.927	2499.839	1303.546	784.4356	446.0565	191.7314	0	8846.536
Coal	19.98431	13.7969	7.194416	4.329389	2.461836	1.058187	0	48.82503
Kerosene	10.41087	7.18752	3.747945	2.255404	1.282499	0.551265	0	25.4355
LPG	7089.75	4894.667	2552.333	1535.919	873.3754	375.4088	0	17321.45
Electricity	160.3295	3496.704	5023.592	6232.724	7194.394	7799.457	7943.135	37850.34
Biogas	4036.698	2786.881	1453.224	874.5078	497.2746	213.7468	0	9862.332
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	157443.3	112082.7	61645.96	40306.41	26569.84	16127.73	7943.135	422119.1

The use of solid fuels, LPG and biogas for water boiling is decreased due to increase in the use of electric water boilers which increases the energy demand for electricity from 19TJ to 298TJ by 2050.

Table 4-37 Energy demand in rural sector for water boiling according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	3439.538	2374.611	1238.245	745.1396	423.7115	182.1267	0	8403.372
Agricultural Residue	18.05072	12.46197	6.498317	3.910497	2.22364	0.955802	0	44.10095
Animal Waste	0.618145	0.426759	0.222534	0.133915	0.076148	0.032731	0	1.510233
Coal	1.801179	1.243509	0.64843	0.390206	0.221884	0.095374	0	4.400583
Kerosene	0	0	0	0	0	0	0	0
LPG	256.2212	176.8916	92.24045	55.5076	31.56349	13.56715	0	625.9915
Electricity	19.68358	140.7018	193.5072	236.9395	271.7641	293.5186	298.1888	1454.304
Biogas	22.7346	15.69566	8.184528	4.92521	2.80064	1.203818	0	55.54445
Briquette	0	0	0	0	0	0	0	0
Solar thermal	2.031312	1.40239	0.731279	0.440062	0.250234	0.10756	0	4.962837
Solar PV	0	0	0	0	0	0	0	0
	3760.679	2723.434	1540.278	1047.387	732.6116	491.6078	298.1888	10594.19

The use of firewood for heating is reduced from 1535.8 TJ to 552.9TJ by 2030 and reaches 0TJ by 2050 and the use of electric heaters and air conditioners causes rise in electricity demand from 28TJ to 206TJ by 2050 due to full electrification target by LTS.

Table 4-38 Energy demand in rural sector for space heating according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	1535.862	1060.338	552.9151	332.7282	189.2004	81.32528	0	3752.369
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	28.03512	107.2789	139.0404	167.0153	189.7559	203.7907	206.2575	1041.174
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	1563.897	1167.617	691.9555	499.7434	378.9563	285.116	206.2575	4793.542

Since electricity is only the source operating fans, blowers, coolers and air conditioners, the electricity demand for space cooling decreases from 1030TJ to 267 TJ by 2050. This decrease is due to rapid urbanization.

Table 4-39 Energy demand in rural sector for space cooling according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	1030.565	825.3259	537.9596	431.6378	368.1657	316.5022	267.0487	3777.204
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	1030.565	825.3259	537.9596	431.6378	368.1657	316.5022	267.0487	3777.204

The use of kerosene in lighting is completely reduced to 0 due to use of energy efficient electric technologies. The shifting of population also causes the decrease in demand of biogas and solar lightings. This also causes decrease in electricity demand decreasing from 948TJ to 305TJ by 2050.

Table 4-40 Energy demand in rural sector for lighting according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	144.4334	0	0	0	0	0	0	144.4334
LPG	0	0	0	0	0	0	0	0
Electricity	948.1529	829.1575	555.467	457.7285	400.6922	353.2953	305.544	3850.037
Biogas	61.98381	42.79278	22.31437	13.42814	7.635691	3.2821	0	151.4369
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	150.5438	103.9334	54.19625	32.61372	18.54526	7.971432	0	367.8038
	1305.114	975.8836	631.9776	503.7703	426.8731	364.5488	305.544	4513.711

Due to the rapid shifting of population to urban areas the demand for electricity used in electrical appliances reduces from 1515TJ to 392T0J by 2050.

Table 4-41 Energy demand in rural sector for electrical appliances according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	0	0	0	0	0	0	0	0
Agricultural Residue	0	0	0	0	0	0	0	0
Animal Waste	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0
Electricity	1515.622	1213.783	791.1616	634.7972	541.4506	465.4706	392.7409	5555.026
Biogas	0	0	0	0	0	0	0	0
Briquette	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	1515.622	1213.783	791.1616	634.7972	541.4506	465.4706	392.7409	5555.026

In other end uses the use of solid fuels, biogas, LPG is reduced substantially increasing the electricity demand from 9TJ to 1337TJ by 2050.

Table 4-42 Energy demand in rural sector for other end uses according to LTS

End use/ year	2021	2025	2030	2035	2040	2045	2050	Total
Firewood	24544.77	16945.38	8836.196	5317.364	3023.633	1299.668	0	59967
Agricultural Residue	434.3586	299.8753	156.3705	94.0992	53.50797	22.99969	0	1061.211
Animal Waste	408.3814	281.941	147.0186	88.47152	50.30789	21.62417	0	997.7446
Coal	0.870727	0.601138	0.313465	0.188634	0.107264	0.046106	0	2.127333
Kerosene	14.68261	10.13667	5.285785	3.180831	1.808728	0.777457	0	35.87208
LPG	1194.619	824.7485	430.0666	258.8015	147.1633	63.25616	0	2918.655
Electricity	9.152268	576.4773	839.48	1045.64	1209.24	1312.377	1337.516	6329.882
Biogas	345.6454	238.6289	124.4335	74.88041	42.57952	18.30224	0	844.4699
Briquette	34.65566	23.9258	12.47615	7.507781	4.269177	1.835049	0	84.66961
Solar thermal	0	0	0	0	0	0	0	0
Solar PV	0	0	0	0	0	0	0	0
	26987.13	19201.71	10551.64	6890.134	4532.616	2740.886	1337.516	72241.64

b. Fuel-wise LTS scenario

According to the source of fuel, the use of firewood is seen in highly decreasing trend and reaches 0 by 2050 to achieve 100% electrification target by LTS. Similarly, the demand of electricity is seen rising due to the use of electric efficient technologies and decreasing the use of renewable fuels.

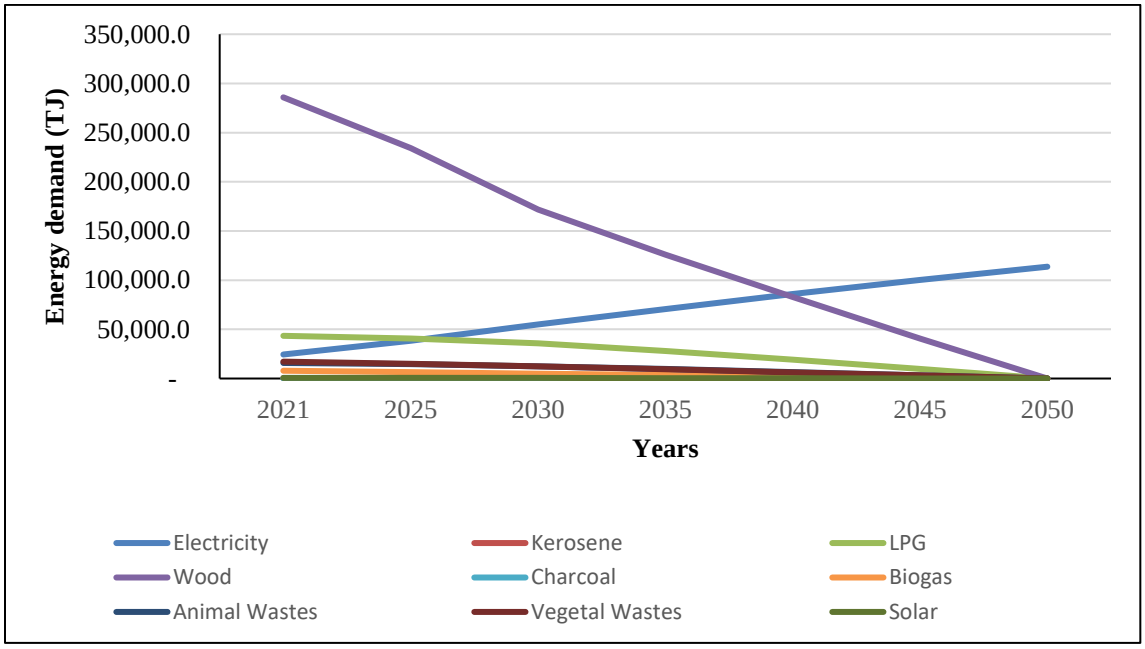


Figure 4-23 Fuel wise electricity demand LTS

Here we can see that the consumption of wood decreases to 73% of total energy usage by 2030 and to 0% by 2050 to achieve 100% electrification. The use of all fuels decreases and electricity demand increases according to the LTS scenario.

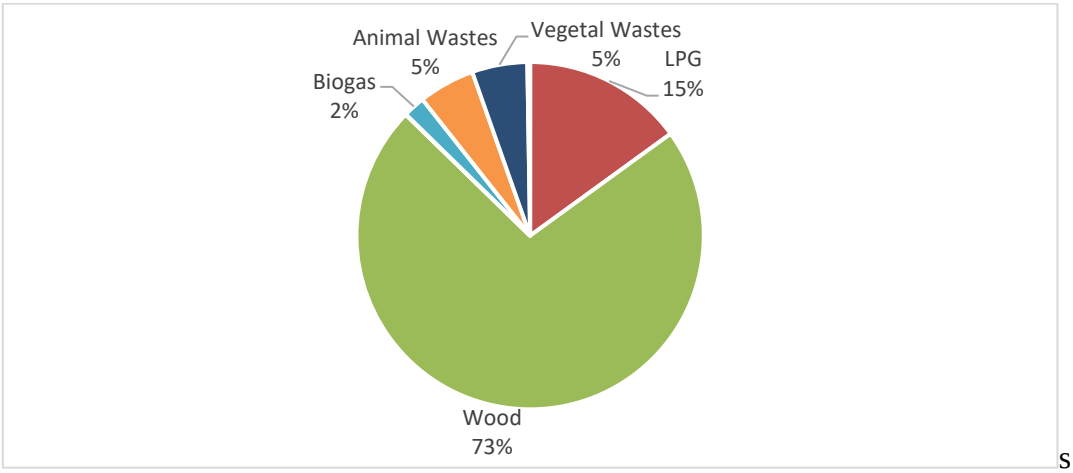


Figure 4-24 Fuel wise demand 2030 LTS

4.1.5 Total Energy in different scenarios

The residential sector's overall energy demand in 2021 amounted to 395.7 petajoules (PJ). However, there are projections indicating that this figure will experience changes under various growth and policy scenarios. In the case of low growth, the energy demand is anticipated to reach a value of 353.3 PJ, while under medium growth conditions, this demand is projected to rise to 356 PJ. In a high growth scenario, the energy demand might climb to 359.7 PJ. Similarly, considering different policy orientations, the energy demand trajectory follows a distinct path. In the context of low growth policy, the demand is foreseen to attain 111.3 PJ, whereas in the case of medium growth policy, it could reach 112.3 PJ. In a high growth policy scenario, the energy demand might escalate to 119.4 PJ. Examining the baseline scenario, often referred to as the Business-As-Usual (BAU) scenario, a slight decline in total energy demand is envisaged. This is attributed to prevailing trends in fuel usage and the relatively lower energy intensity of electric appliances compared to traditional wood fuel sources. Conversely, the policy scenarios, which are designed to promote energy efficiency and sustainability, paint a different picture. The energy demand is predicted to undergo a substantial reduction by 2030 under these policy-driven trajectories. This can be primarily attributed to the adoption of more energy-efficient practices and technologies facilitated by these policies. Furthermore, the trend is expected to continue albeit at a slower pace up to the year 2050. This decrease can be attributed to the consistent implementation of the electrification approach and the integration of energy-efficient electrical equipment, both of which are central to the policy strategies. In essence, while the baseline scenario suggests a modest decline in energy demand due to current trends, the policy scenarios introduce a promising avenue for substantial energy reduction through the concerted efforts of electrification and the promotion of energy-efficient practices across the residential sector.

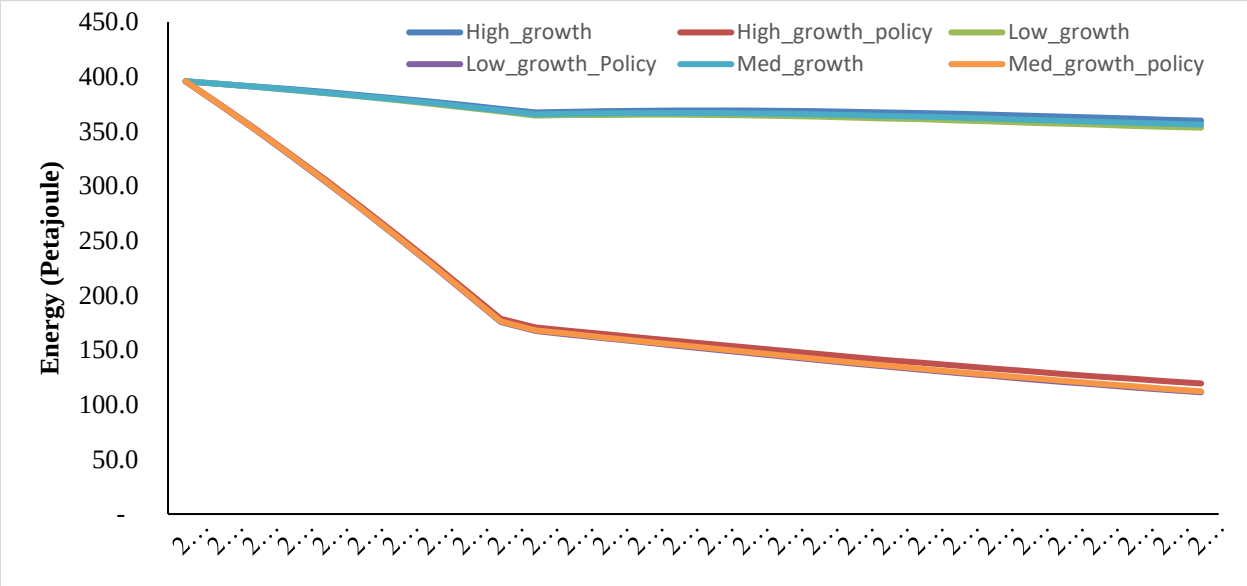
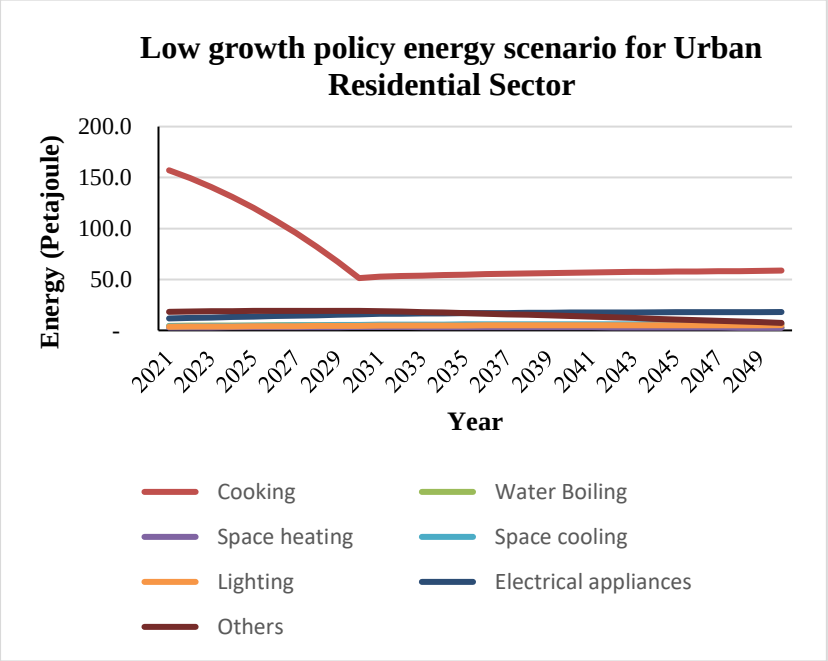
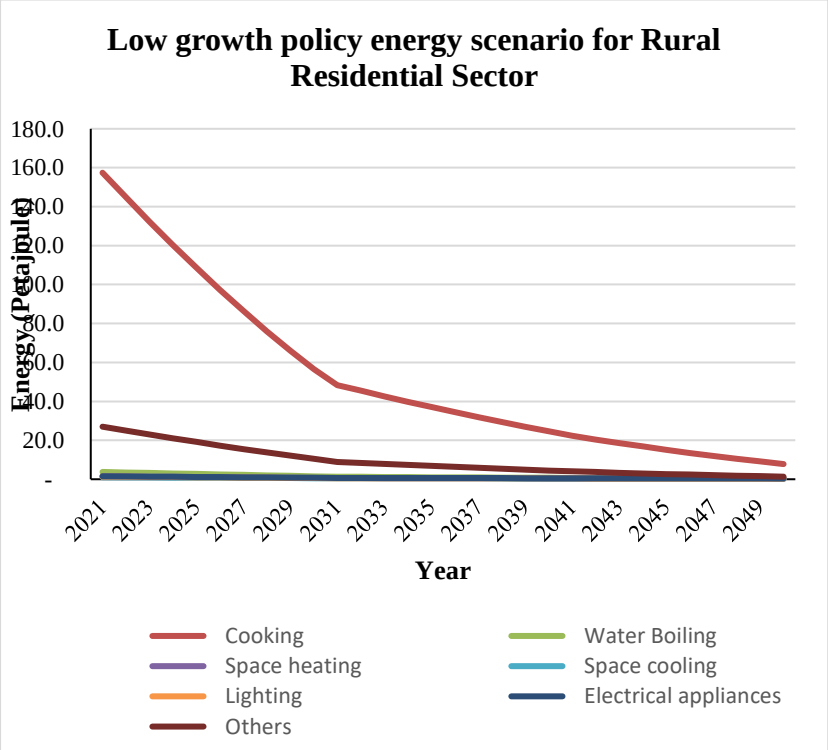


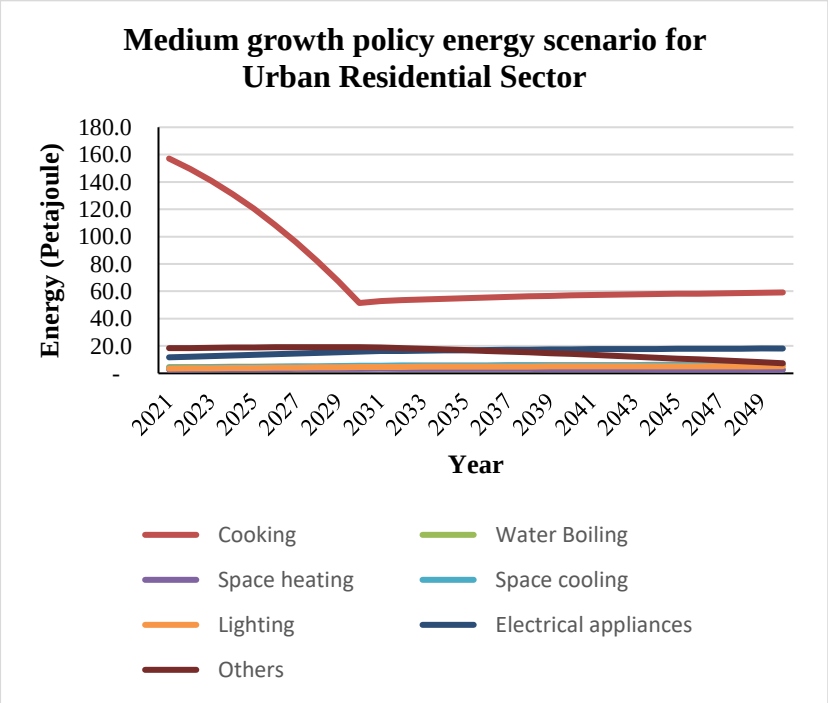
Figure 4-25 Total energy in different scenarios



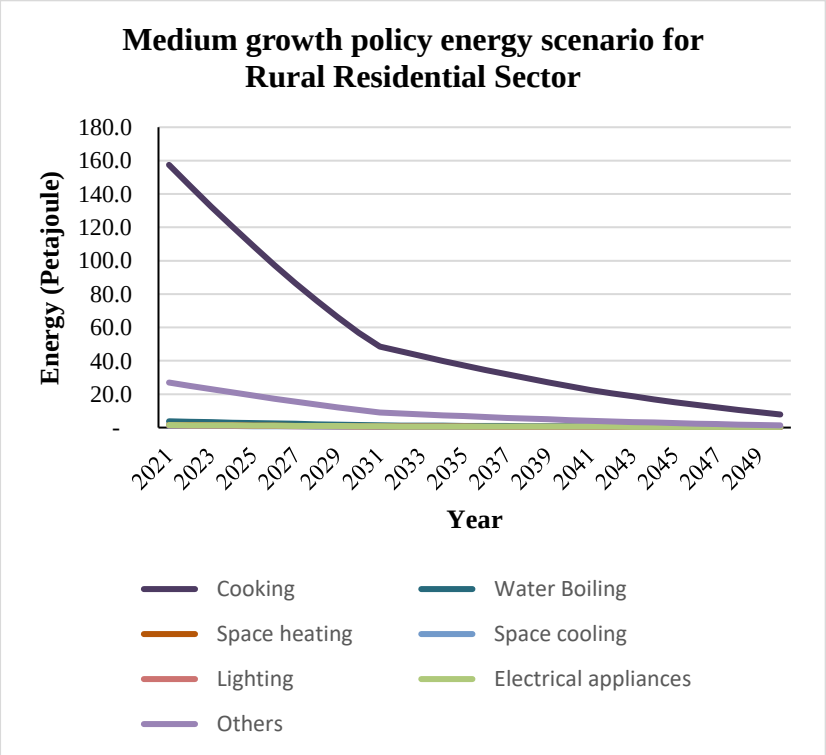
- 202.1 PJ worth of energy was needed in urban areas in 2021.
- This is anticipated to drop to 100.8PJ under a low growth policy scenario.
- This energy requirement includes a sizable portion from cooking activities.
- The estimated reduction in cooking energy use to 58.6PJ by 2030.
- Due to growing urban homes, urban cooking has been rapidly electrified, which causes decrement



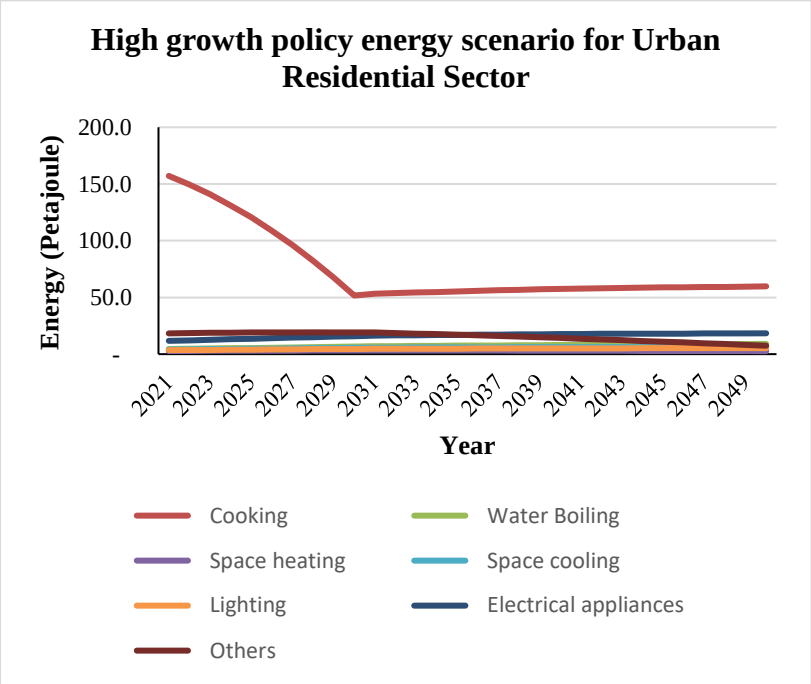
- In 2021, rural energy needs were 193.6 PJ.
- Under a low growth policy scenario, this is expected to decrease sharply to 10.5 PJ.
- Cooking activities make up a significant portion of rural energy consumption, accounting for 157.4 PJ in 2021.
- By 2030, this is projected to drop to 7.8 PJ.
- Two main factors contribute to this reduction: rapid electrification initiatives and rural-to-urban migration.
- Electrification strategies are driving the shift to energy-efficient cooking practices.



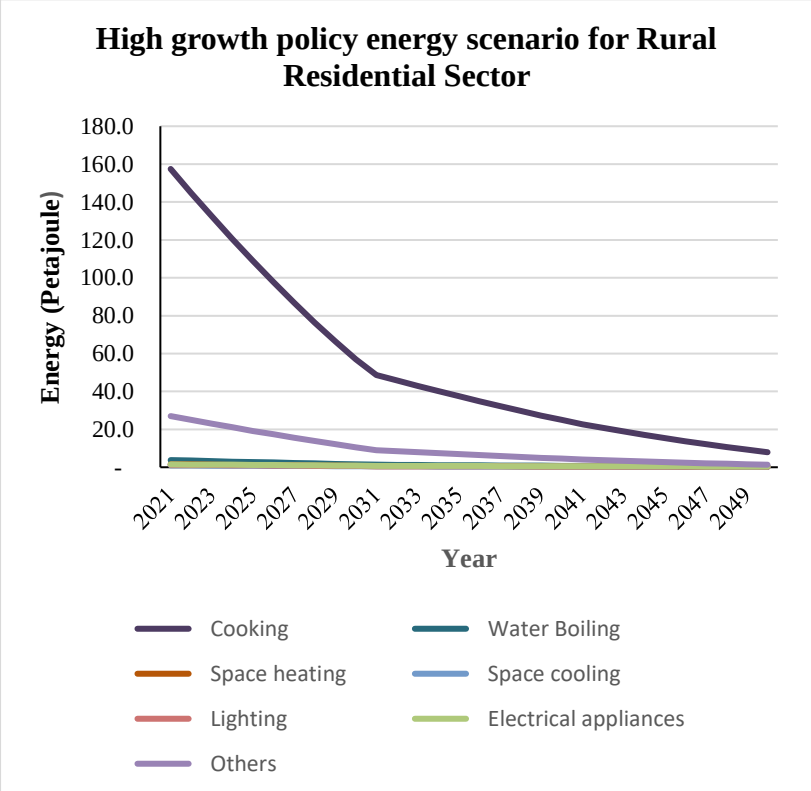
- In 2021, urban energy requirements were 202.1 PJ.
- Under a medium growth policy scenario, this is expected to decrease to 101.6 PJ.
- Cooking activities play a significant role in urban energy consumption, accounting for 157.1 PJ in 2021.
- By 2030, this is projected to decrease notably to 59.1 PJ.
- Two main factors drive this reduction: rapid electrification initiatives and the use of energy-efficient electrical appliances.



- In 2021, rural energy requirements were 193.6 PJ.
- Under a medium growth policy scenario, this is expected to decrease to 10.6 PJ.
- Cooking activities have a significant impact on rural energy consumption, accounting for 157.4 PJ in 2021.
- By 2030, this is projected to decrease notably to 7.8 PJ.
- Two main factors drive this reduction: rapid electrification initiatives and rural-to-urban population migration.



- In 2021, urban energy requirements were 202.1 PJ.
- Under a high growth scenario, this is expected to decrease to 108.7 PJ.
- Cooking activities have a significant impact on urban energy consumption, accounting for 157.1 PJ in 2021.
- By 2030, this is projected to decrease notably to 59.7 PJ.
- The primary driver of this reduction is the rapid and comprehensive adoption of electrification strategies.



- In 2021, rural energy requirements were 193.6 PJ.
- Under a high growth policy scenario, this is expected to decrease to 10.7 PJ.
- Cooking activities have a significant impact on rural energy consumption, accounting for 157.4 PJ in 2021.
- By 2030, this is projected to decrease significantly to 7.9 PJ.
- The primary drivers of this reduction are rapid electrification strategies and rural-to-urban population migration.

4.1.6 Power generation requirements

To fulfil the electricity requirements in case of Sustainable Development Goal Scenario for year 2030, 9643.972 megawatt of electricity production is required with urban sector requiring 8009.155 MW of electricity production whereas rural sector requires the production of 1634.8MW of electricity. Similarly, 14831.98MW of total electricity is required to be produced to meet the required targets of SDG with urban sector requiring production of 13428.49MW and rural sector requiring the total production of 1403.499. This production requirement is decreased in rural sector due to the quick shifting of large population to urban areas.

Table 4-43 Power generation requirement according to Sustainable development Goals (SDG)

End-use/year	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Cooking	2248.151	951.0502	**3199.201**	3776.575	668.7671	**4445.342**
Water boiling	718.3562	147.3973	**865.7534**	2290.137	226.8493	**2516.986**
Space Heating	498.4127	61.26984	**559.6825**	1129.524	90.95238	**1220.476**
Space Cooling	764.95	74.7	**839.65**	884.85	37.1	**921.95**
Lighting	975.1076	120.2348	**1095.342**	1127.906	65.59687	**1193.503**
Electrical appliances	2419.726	120.4384	**2540.164**	2799.014	59.78082	**2858.795**
Others	384.4521	159.726	**544.1781**	1420.479	254.4521	**1674.932**
Total	**8009.155**	**1634.817**	**9643.972**	**13428.49**	**1403.499**	**14831.98**

To fulfil the electricity requirements in case of Second Nationally Determined Contribution (NDC) for year 2030, 2540.164 megawatt of electricity production is required with urban sector requiring 2419.746 MW of electricity production whereas rural sector requires the production of 120.4384MW of electricity. Similarly, 2858.795MW of total electricity is required to be produced to meet the required targets of NDC with urban sector requiring production of 2799.014MW and rural sector requiring the total production of 59.78MW. This production requirement is less in comparison to SDG because NDC focuses on increasing the use of LPG by 30% and biogas fuels in houses rather than solely relying on electricity.

Table 4-44 Power generation requirement according to Second Nationally Determined Contribution (NDC)

End-use/year	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Cooking	2459.178	761.0959	**3220.274**	8950.342	1208.082	**10158.42**
Water boiling	494.7945	114.2466	**609.0411**	1801.37	181.3699	**1982.74**
Space Heating	501.4286	61.26984	**562.6984**	1141.111	90.95238	**1232.063**
Space Cooling	764.95	74.7	**839.65**	884.85	37.1	**921.95**
Lighting	953.5812	118.8258	**1072.407**	1127.906	63.24853	**1191.155**
Electrical appliances	2419.726	120.4384	**2540.164**	2799.014	59.78082	**2858.795**
Others	384.4521	159.726	**544.1781**	1420.479	254.4521	**1674.932**
Total	**7978.11**	**1410.303**	**9388.413**	**18125.07**	**1894.986**	**20020.06**

To fulfil the electricity requirements in case of Nepal's long term strategy for net zero emissions (LTS), for year 2030, 11112.06 MW of electricity production is required with urban sector requiring 8991.418 MW of electricity production whereas rural sector requires the production of 2120.638 MW of electricity. Similarly, 23974.73MW of total electricity is required to be produced to meet the required targets of LTS with urban sector requiring production of 21063.04MW and rural sector requiring the total production of 2911.693MW. This production requirement is more in comparison to SDG and NDC focuses on increasing the use of electricity rather than using other renewable sources. Since the per capita GDP is targeted to reach 7% and electrification is expected to reach 100% by 2050.

Table 4-45 Power generation requirements according to LTS strategy

End-use/year	2030			2050		
	Urban	Rural	Total	Urban	Rural	Total
Cooking	3243.288	1274.338	**4517.626**	11378.56	2014.977	**13393.54**
Water boiling	718.3562	147.3973	**865.7534**	2290.137	226.8493	**2516.986**
Space Heating	501.4286	142.963	**644.3915**	1141.111	212.2222	**1353.333**
Space Cooling	764.95	74.7	**839.65**	884.85	37.1	**921.95**
Lighting	959.2172	120.7828	**1080**	1148.885	66.45793	**1215.342**
Electrical appliances	2419.726	200.7306	**2620.457**	2799.014	99.6347	**2898.648**
Others	384.4521	159.726	**544.1781**	1420.479	254.4521	**1674.932**
Total	**8991.418**	**2120.638**	**11112.06**	**21063.04**	**2911.693**	**23974.73**

4.2 Electricity forecasting

4.2.1 Total electricity demand in different scenarios

In 2021, residential electricity demand was 6782.3 GWh. Projections suggest various growth scenarios for the future. In the low growth scenario, demand is expected to increase to 9173.3 GWh, with medium and high growth scenarios projecting 9294.4 GWh and 9343.5 GWh, respectively. Policy scenarios, such as low growth policy, medium growth policy, and high growth policy, could lead to demand values of 30928.7 GWh, 31183.7 GWh, and 30668.3 GWh. The Business-As-Usual (BAU) scenario predicts a modest increase in demand due to fuel trends and urbanization. However, policy interventions can significantly affect demand trajectories, emphasizing the importance of proactive energy management and policy design in shaping residential electricity consumption. Overall, these scenarios highlight the need for informed decision-making in managing residential energy demand.

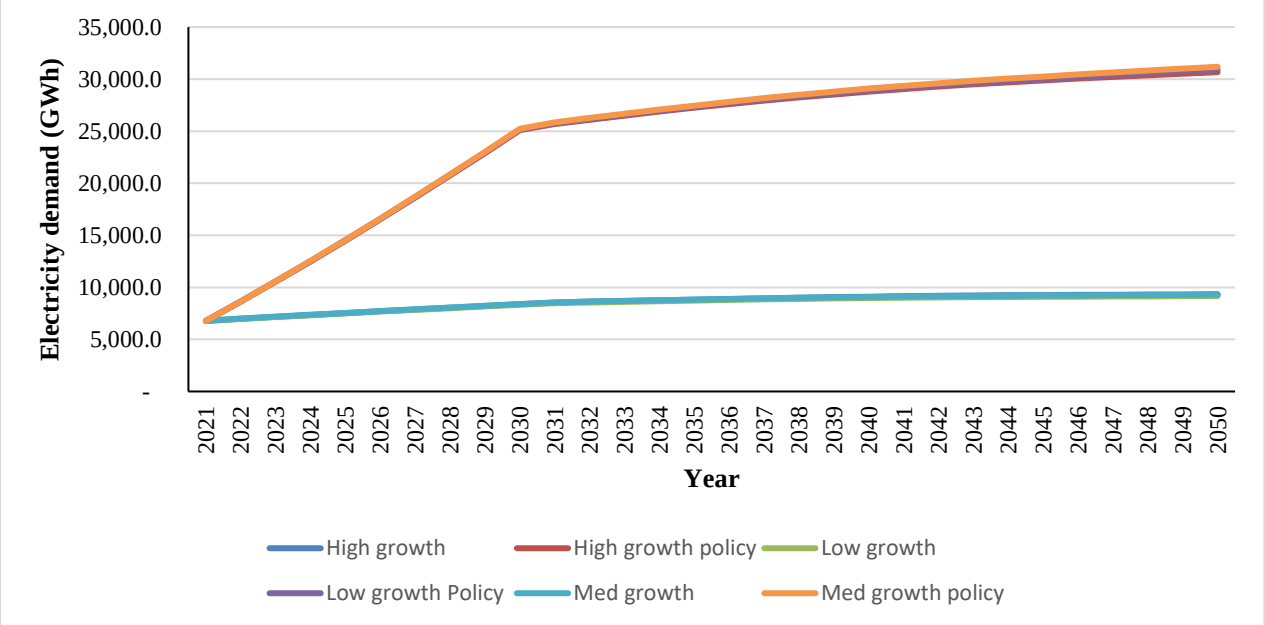
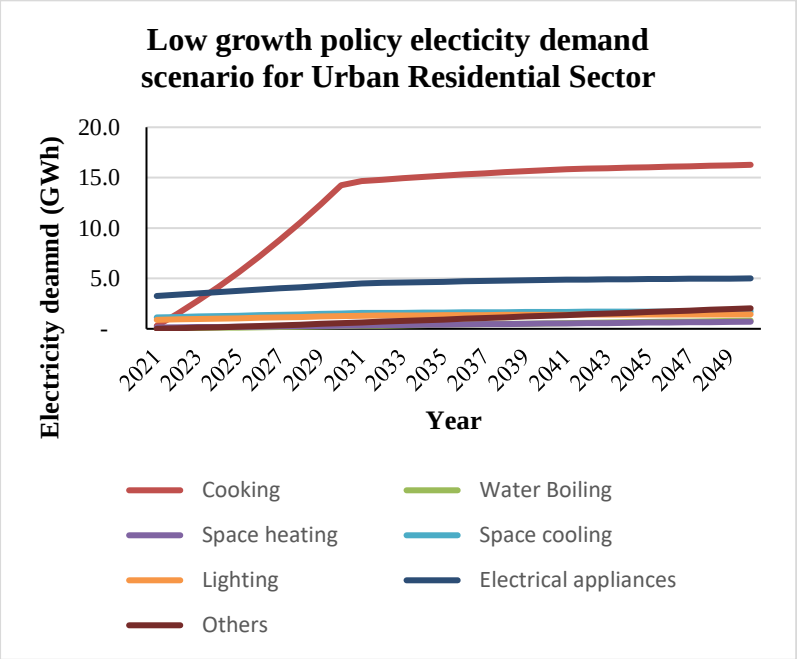
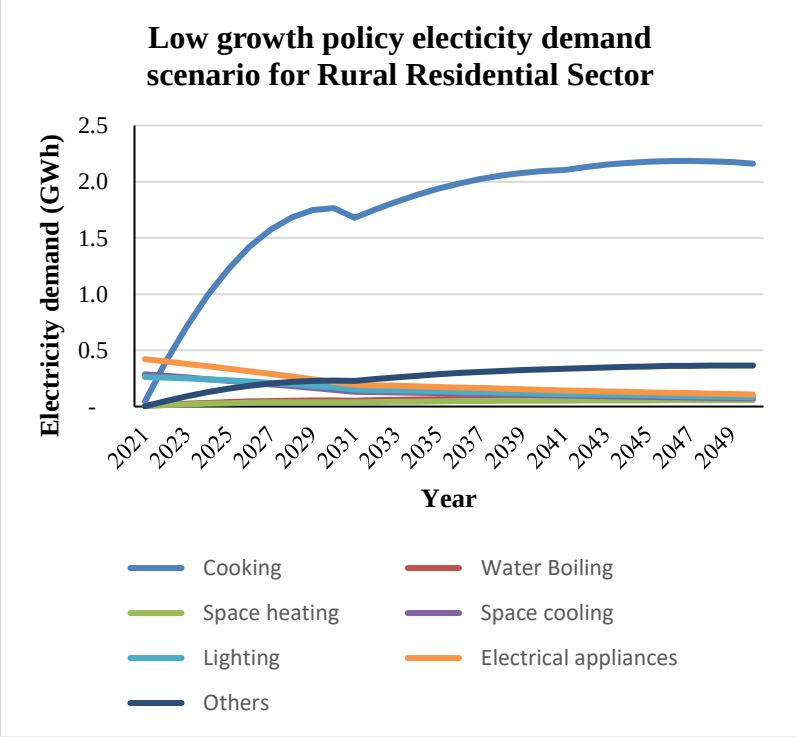


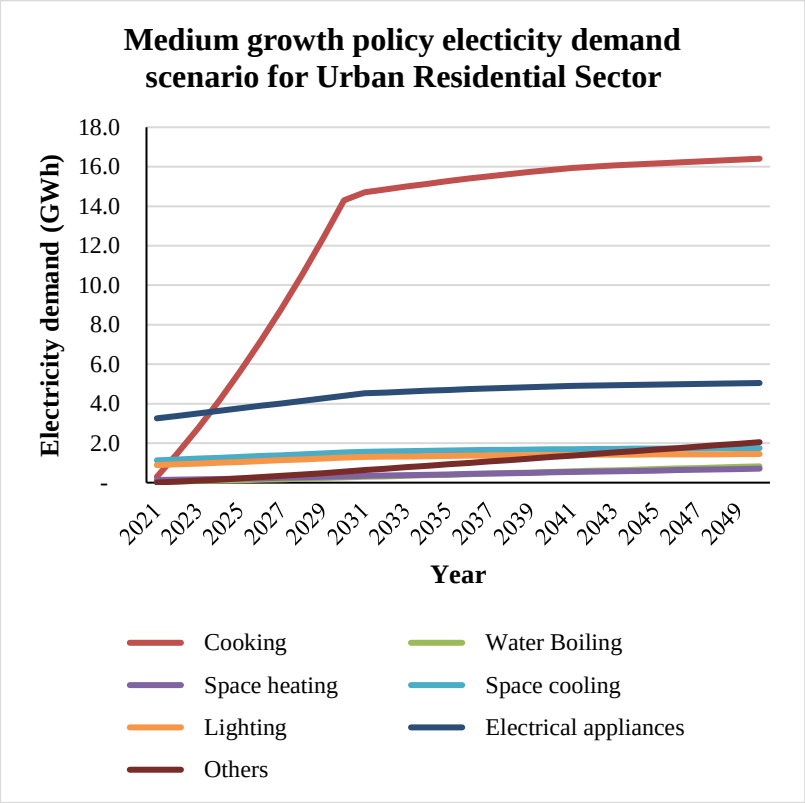
Figure 4-26 Total electricity demand in different scenarios



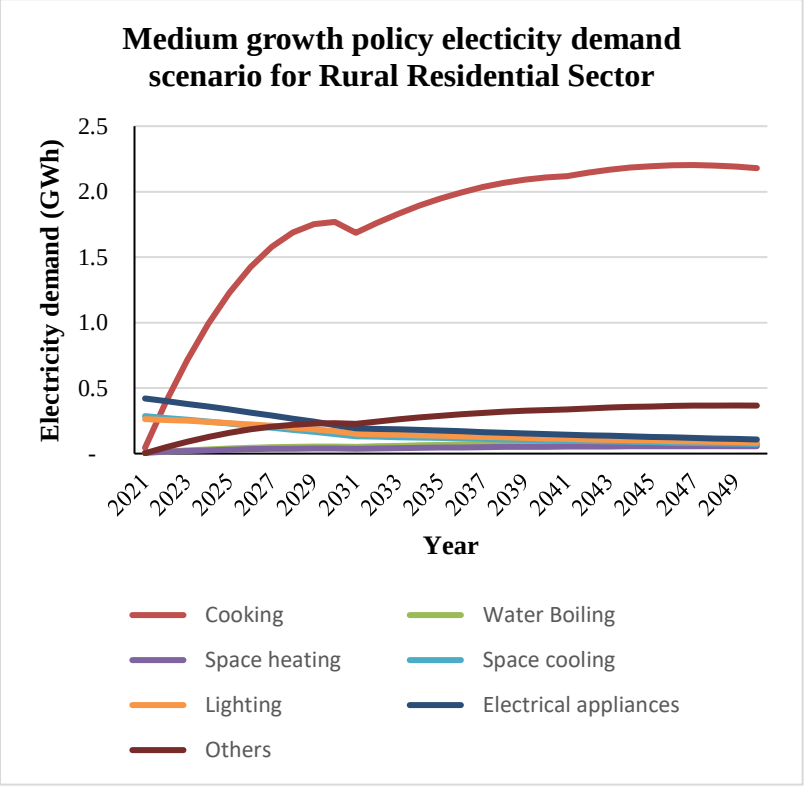
- In 2021, urban electricity consumption was 5.8 GWh.
- Under a low growth policy scenario, this is expected to increase significantly to 28 GWh.
- Cooking activities contribute significantly to urban electricity demand, accounting for 0.3 GWh in 2021 which is projected to rise to 16.3 GWh.
- The increase in electricity usage for urban cooking is driven by rapid electrification efforts and an expanding urban population.



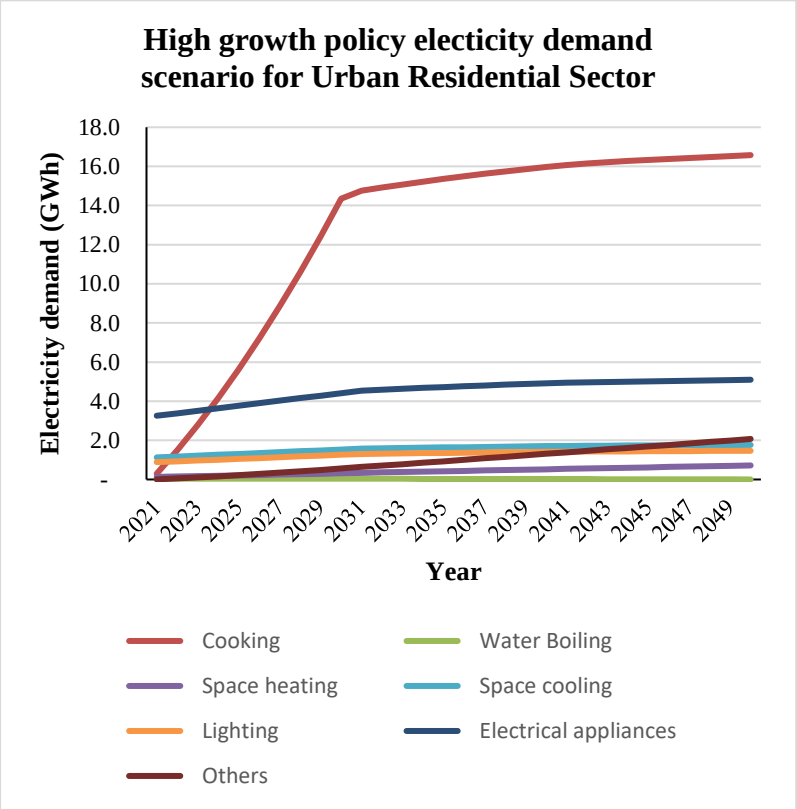
- In 2021, rural electricity consumption was 1 GWh.
- Under a low growth policy scenario, this is expected to increase to 2.9 GWh.
- Cooking contributes to rural electricity demand, accounting for 0 GWh in 2021.
- By 2030, this is projected to notably rise, possibly reaching 2.2 GWh.
- The increase in electricity usage for rural cooking is driven by two main factors: a decrease in rural households and rapid electrification initiatives.



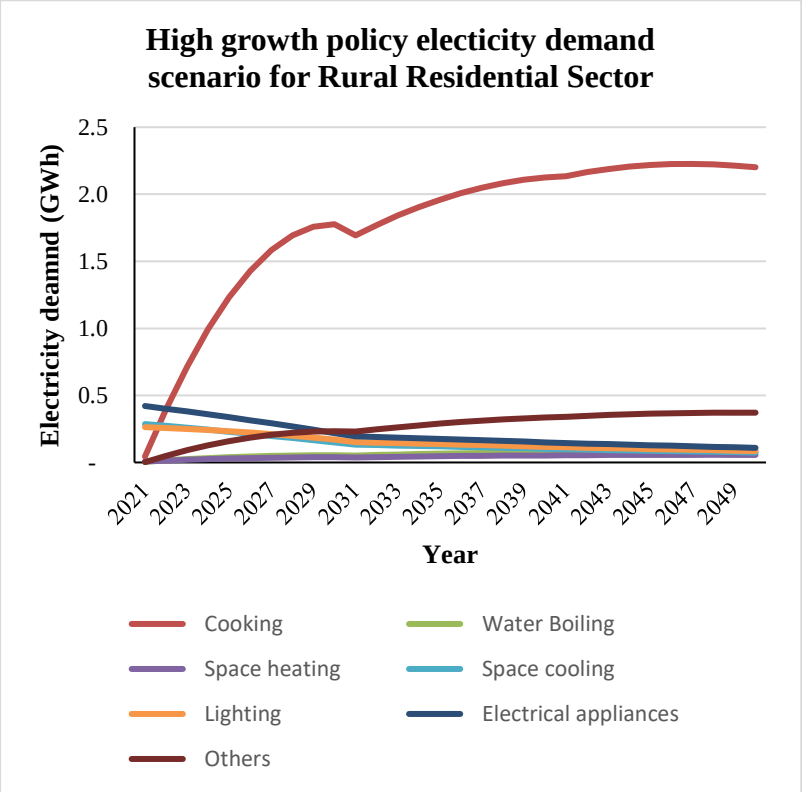
- In 2021, urban electricity consumption was 5.8 GWh.
- Under a medium growth policy scenario, this is expected to increase to 28.2 GWh.
- Cooking-related activities contribute significantly to urban electricity demand, accounting for 0.3 GWh in 2021.
- By 2030, this is projected to notably rise to 16.4 GWh.
- The primary driver of this increase is the rapid implementation of electrification strategies for cooking.



- In 2021, rural electricity consumption was 1 GWh.
- Under a medium growth policy scenario, this is expected to increase to 2.9 GWh.
- Cooking activities significantly contribute to rural electricity demand, accounting for 0 GWh in 2021.
- By 2030, this is projected to notably rise to 2.2 GWh.
- The increase in electricity usage for rural cooking is driven by two main factors: a decrease in rural households and robust electrification strategies.



- In 2021, urban electricity consumption was 5.8 GWh.
- Under a high growth policy scenario, this is expected to increase significantly to 27.7 GWh.
- Cooking-related activities significantly contribute to urban electricity demand, accounting for 0.3 GWh in 2021.
- By 2030, this is projected to notably rise to 16.6 GWh.
- The primary driver of this increase is the rapid and comprehensive deployment of electrification strategies for cooking.



- In 2021, rural electricity consumption was 1 GWh.
- Under a high growth policy scenario, this is expected to increase to 3 GWh.
- Cooking activities significantly contribute to rural electricity demand, accounting for 0 GWh in 2021 which is projected to rise, potentially reaching 2.2 GWh by 2030.
- The increase in electricity usage for rural cooking is driven by two main factors: a decrease in rural households and rapid electrification strategies.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research provides workable strategies to promote sustainable power demand creation, enhance energy efficiency, and ensure reliable access to electricity in residential sectors across Nepal. The prediction of the overall demand for energy is also not thoroughly researched. 43.3% of the electricity is consumed by residential families. As a result, the switch to electrical appliances in this industry has emerged as a research topic. There isn't much writing on the subject. They emphasize total electricity and energy use. There is not much study on how to boost home energy consumption. Energy use in the residential sector Electricity consumption will rise from 9075.49 GJ in 2019 to 11668.28 GJ in 2021.Since electricity is only used for 0.4% of cooking, Nepal has the option to transition to electric cooking in the future. The computed Compounded Annual Growth pace (CAGR) is 9.586%, indicating that the pace at which power consumption is increasing. The fastest growth was seen in the residential sector. The peak hour demand has increased from 1847.52 GWh to 11632.15 GWh in 2030. The production requirement according to Sustainable Development Goals (SDG) strategy was found to be 9643.972MW by 2030 and 23974.73MW by 2050. Similarly, according to second Nationally Determined Contribution (NDC) strategy the total electricity generation requirement in 2030 was found to be 9388.413MW and in 2050 it was found to be 20020.06MW. Similarly, according to Long Term strategy for zero emissions (LTS) strategy the power generation requirement was found to be 11112.06MW by 2030 and 23974.73MW by 2050. According to SDG strategy, we can see that by 2030 the use of wood is decreases to 53% of total energy usage and decreases to 0% by 2050 to meet the SDG target and the electricity consumption increases to 17% of total energy usage by 2030. Similarly, the use of electricity and LPG increases highly to reach 44% and 56% respectively by 2050 which accounts for all the energy use by 2050. According to LTS strategy. Similarly, according to NDC we can see that the use of wood is decrease to 57% of total energy usage by 2030 and is targeted to decrease to 0% by 2050. Due to the decrease in use of solid fuels, the consumption of electricity increases by a substantial amount increasing by 17% in 2030 to 77% of total energy usage by 2050. The use of LPG and biogas is also increased due to NDC's target of increasing the volume of improved and electric cookstoves and biogas plants by 2030. According to the LTS strategy, we can see that the consumption of wood decreases to 73% of total energy usage by 2030 and to 0% by 2050 to achieve 100% electrification. The use of all fuels decreases and electricity demand increases according to the LTS scenario.

This means that there is also a strong demand for the operation of electrically powered components in the home sector. When creating scenarios for the potential future energy consumption utilizing various fuel sources, growth rates such as Low Growth Scenario, Medium Growth Scenario, High Growth Scenario, and Policy Scenario were considered. Utilizing publicly released papers and records from Nepali government organizations, these growth rates were computed. An estimation

of demand for various residential subsectors is generated by LEAP using these factors as input. In overall residential sector, it is found that electricity demand increases from 6844.6 GWh in the base year to 7765.8 GWh, 7687.3 GWh and 7624.4 GWh for high, medium and low growth rate respectively scenario by 2050.

5.2 Recommendation

This research project focuses on examining the variables influencing the rise in energy demand in various Nepalese residential sectors from the base year to the year 2050. 0These programs are intended to support sustainability and resilience in the energy industry by being in line with both BAU projections and policy-driven scenarios.

- Investment in Infrastructure: Develop and upgrade electricity generation, transmission, and distribution infrastructure to ensure a reliable and efficient supply of electricity to meet increasing demand.
- Technology transformation: Promoting the adoption of electric end-use appliances over conventional fuel-based appliances.
- Energy efficient programs: Launching targeted energy-efficiency campaigns and programs with the goal of encouraging residential consumers to practice energy-conscious behavior. Along with developing energy-efficient construction norms and standards, this also entails teaching households about energy-efficient equipment and offering incentives for adoption.
- Demand side management (DSM): putting into practice load-shifting and peak demand reduction solutions for demand side management. For example, time-of-use pricing, demand response initiatives, and smart metering infrastructure might all be used to entice customers to use less electricity at peak times.
- Renewable Energy Integration: The installation of solar panels and small-scale wind turbines for household use should be increased. These decentralized energy sources can be more quickly adopted by providing incentives, subsidies, and simple access to finance choices.
- Grid modernization: Upgrading and modernizing the electrical system to facilitate two-way energy flows, accommodate distributed energy resources, and enhance reliability. Smart grids and microgrids are examples of advanced grid technology that can increase system resilience and flexibility.
- Energy storage solutions: promoting the use of household energy storage systems, such as batteries, to store surplus energy from inconsistent renewable sources. These devices can support a stable grid by acting as a backup power source during blackouts.
- Public awareness campaigns: launching public awareness efforts to inform citizens of the value of prudent power use. Increasing public awareness of the sociological, economic, and environmental advantages of sustainable energy methods can influence behavior.

- Incentive mechanisms: Putting in place financial incentives, tax breaks, and subsidies to encourage developers and residential customers to spend money on energy-efficient appliances, renewable energy sources, and energy-saving technologies.
- Policy and regulatory frameworks: Creating and implementing laws and policies that encourage the use of demand-side energy management techniques, energy-efficient technologies, and renewable energy sources. Innovation and investment can be boosted by fostering an atmosphere that welcomes private sector involvement.

The ability of Nepal to successfully meet the rising electricity demand in the residential sector will determine how quickly the country can transition to a sustainable and resilient energy future. Nepal can develop a comprehensive strategy that is in line with BAU estimates and policy-driven scenarios by putting into practice a combination of the advised strategic objectives. Energy security and environmental stewardship for future generations will be ensured through these projects, which cover energy efficiency, renewable energy integration, grid modernization, and public awareness. They will help Nepal develop a more sustainable and resilient energy landscape.

5.3 Future Works

This research study focuses on projecting electricity demand in different residential sectors in Nepal up to the year 2050. However, there is scope for additional research to investigate electricity demand creation and emission characteristics in various other economic sectors, including industrial, transport, commercial, agriculture, construction, and mining sectors. This extended research can encompass different administrative levels, such as local, provincial, and federal systems, providing a comprehensive understanding of electricity usage and advantages of demand creation throughout the country.

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ANNEX – I

Energy Consumption in Industrial Sector (Fuel Wise)

Fuel / end use	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliances	Others	Total
Wood	229,651	6,211	1,660	0	0	0	35,720	273,243
Agricultural residue	16,127	120	0	0	0	0	936	17,183
Animal waste	13,459	1	0	0	0	0	2,469	15,930
Coal	66	2	0	0	0	0	1	69
kerosene	23	0	0	0	381	0	27	431
LPG	37,263	1,253	20	0	0	0	5,100	43,636
Electricity	1,230	165	500	5,092	4,149	13,244	29	24,410
biogas	7,312	54	0	0	62	0	508	7,937
briquettes	21	0	12	0	0	0	40	73
Solar thermal	0	384	0	0	0	0	0	384
Solar PV	0	0	0	0	224	0	0	224
Total	305,153	8,191	2,193	5,092	4,816	13,244	44,831	383,519

Fuel / end use	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliances	Others	Total
Wood	102,683	2,885	2,305	0	0	0	12,826	120,699
Agricultural residue	9,996	102	0	0	0	0	502	10,599
Animal waste	9,839	0	0	0	0	0	2,061	11,900
Coal	46	0	0	0	0	0	0	46
kerosene	14	0	0	0	238	0	12	264
LPG	30,173	997	20	0	0	0	3,908	35,098
Electricity	1,071	146	474	4,063	3,203	11,729	20	20,706
biogas	3,274	31	0	0	0	0	163	3,469
briquettes	20	0	12	0	0	0	5	37
Solar thermal	0	382	0	0	0	0	0	382
Solar PV	0	0	0	0	74	0	0	74
Total	157,121	4,545	2,811	4,063	3,512	11,729	19,494	203,276

Fuel / end use	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliances	Others	Total
Wood	136,374	3,440	1,536	0	0	0	24,545	165,894
Agricultural residue	6,131	18	0	0	0	0	434	6,584
Animal waste	3,621	1	0	0	0	0	408	4,030
Coal	20	2	0	0	0	0	1	23
kerosene	10	0	0	0	144	0	15	170
LPG	7,090	256	0	0	0	0	1,195	8,541
Electricity	160	20	28	1,031	948	1,516	9	3,712
biogas	4,037	23	0	0	62	0	346	4,467
briquettes	0	0	0	0	0	0	35	35
Solar thermal	0	2	0	0	0	0	0	2
Solar PV	0	0	0	0	151	0	0	151
Total	157,440	3,760	1,563	1,031	1,306	1,516	26,984	193,599

Fuel / end use	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliances	Others
Wood	75.26	75.83	75.72	0.00	0.00	0.00	79.68
Agricultural residue	5.28	1.47	0.00	0.00	0.00	0.00	2.09
Animal waste	4.41	0.01	0.00	0.00	0.00	0.00	5.51
Coal	0.02	0.02	0.00	0.00	0.00	0.00	0.00
kerosene	0.01	0.00	0.00	0.00	7.91	0.00	0.06
LPG	12.21	15.30	0.91	0.00	0.00	0.00	11.38
Electricity	0.40	2.02	22.82	100.00	86.15	100.00	0.07
biogas	2.40	0.66	0.00	0.00	1.29	0.00	1.13
briquettes	0.01	0.00	0.55	0.00	0.00	0.00	0.09
Solar thermal	0.00	4.69	0.00	0.00	0.00	0.00	0.00
Solar PV	0.00	0.00	0.00	0.00	4.65	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Fuel / end use	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliances	Others
Wood	65.353045	63.4794602	81.9974391	0.0000000	0.000000	0.0000000	65.793102
Agricultural residue	6.3617647	2.2397379	0.0000000	0.0000000	0.000000	0.0000000	2.574762
Animal waste	6.2619033	0.0000000	0.0000000	0.0000000	0.000000	0.0000000	10.571209
Coal	0.0290944	0.0000000	0.0000000	0.0000000	0.000000	0.0000000	0.001421
kerosene	0.0089641	0.0000000	0.0000000	0.0000000	6.769222	0.0000000	0.063146
LPG	19.2038269	21.9376847	0.7188991	0.0000000	0.000000	0.0000000	20.044710
Electricity	0.6818061	3.2141033	16.8541248	100.0000000	91.184413	100.0000000	0.102378
biogas	2.0840211	0.6890069	0.0000000	0.0000000	0.000000	0.0000000	0.837073
briquettes	0.0126751	0.0017416	0.4287293	0.0000000	0.000000	0.0000000	0.026729
Solar thermal	0.0000000	8.4109999	0.0000000	0.0000000	0.000000	0.0000000	0.000000
Solar PV	0.0000000	0.0000000	0.0000000	0.0000000	2.095786	0.0000000	0.000000
Total	100.0000000	100.0000000	100.0000000	100.0000000	100.000000	100.0000000	100.000000

Fuel / end use	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliances	Others
Wood	86.6196997	91.4836023	98.2461871	0.0000000	0.00000000	0.0000000	90.9596789
Agricultural residue	3.8943664	0.4801065	0.0000000	0.0000000	0.00000000	0.0000000	1.6096758
Animal waste	2.2998804	0.0164412	0.0000000	0.0000000	0.00000000	0.0000000	1.5134078
Coal	0.0126933	0.0479071	0.0000000	0.0000000	0.00000000	0.0000000	0.0032268
kerosene	0.0066126	0.0000000	0.0000000	0.0000000	11.05802330	0.0000000	0.0544118
LPG	4.5031490	6.8148781	0.0000000	0.0000000	0.00000000	0.0000000	4.4270996
Electricity	0.1018354	0.5235367	1.7933544	100.0000000	72.59191275	100.0000000	0.0339171
biogas	2.5639623	0.6046866	0.0000000	0.0000000	4.74556754	0.0000000	1.2809162
briquettes	0.0000000	0.0000000	0.0000000	0.0000000	0.00000000	0.0000000	0.1284293
Solar thermal	0.0000000	0.0540281	0.0000000	0.0000000	0.00000000	0.0000000	0.0000000
Solar PV	0.0000000	0.0000000	0.0000000	0.0000000	11.52584279	0.0000000	0.0000000
Total	100.0000000	100.0000000	100.0000000	100.0000000	100.0000	100.0000000	100.0000000

Fuel / end use	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliances	Others	Total
Wood	22.6383	0.6360	0.5082	0.0000	0.0000	0.0000	2.8277	26.6103
Agricultural residue	2.2037	0.0224	0.0000	0.0000	0.0000	0.0000	0.1107	2.3368
Animal waste	2.1691	0.0000	0.0000	0.0000	0.0000	0.0000	0.4543	2.6235
Coal	0.0101	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0101
kerosene	0.0031	0.0000	0.0000	0.0000	0.0524	0.0000	0.0027	0.0582
LPG	6.6522	0.2198	0.0045	0.0000	0.0000	0.0000	0.8615	7.7380
Electricity	0.2362	0.0322	0.1045	0.8959	0.7061	2.5858	0.0044	4.5650
biogas	0.7219	0.0069	0.0000	0.0000	0.0000	0.0000	0.0360	0.7648
briquettes	0.0044	0.0000	0.0027	0.0000	0.0000	0.0000	0.0011	0.0082
Solar thermal	0.0000	0.0843	0.0000	0.0000	0.0000	0.0000	0.0000	0.0843
Solar PV	0.0000	0.0000	0.0000	0.0000	0.0162	0.0000	0.0000	0.0162
Total	34.6401	1.0019	0.6198	0.8959	0.7744	2.5858	4.2978	44.8157

Fuel / end use	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliances	Others	Total
Wood	61.2848353	1.5456884	0.6901982	0.0000000	0.0000000	0.0000000	11.0301322	74.5508542
Agricultural residue	2.7553271	0.0081118	0.0000000	0.0000000	0.0000000	0.0000000	0.1951957	2.9586345
Animal waste	1.6272025	0.0002778	0.0000000	0.0000000	0.0000000	0.0000000	0.1835218	1.8110022
Coal	0.0089807	0.0008094	0.0000000	0.0000000	0.0000000	0.0000000	0.0003913	0.0101815
kerosene	0.0046785	0.0000000	0.0000000	0.0000000	0.0649067	0.0000000	0.0065982	0.0761834
LPG	3.1860506	0.1151428	0.0000000	0.0000000	0.0000000	0.0000000	0.5368477	3.8380411
Electricity	0.0720502	0.0088456	0.0125987	0.4631237	0.4260888	0.6811027	0.0041129	1.6679225
biogas	1.8140447	0.0102167	0.0000000	0.0000000	0.0278548	0.0000000	0.1553290	2.0074452
briquettes	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0155738	0.0155738
Solar thermal	0.0000000	0.0009128	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0009128
Solar PV	0.0000000	0.0000000	0.0000000	0.0000000	0.0676526	0.0000000	0.0000000	0.0676526
Total	70.7516137	1.6895797	0.7025191	0.4631237	0.5869646	0.6811027	12.1263975	87.0013010

Table 5-1 high growth low growth and medium growth BAU scenarios for rural residential sector

Scenario	2021	2025	2030	2035	2040	2045	2050
High_growth	1,072.8	1,115.1	1,158.9	1,191.1	1,210.7	1,217.2	1,217.2
Low_growth	1,072.8	1,111.7	1,150.9	1,178.4	1,193.2	1,195.0	1,195.0
Med_growth	1,072.8	1,113.3	1,154.5	1,184.0	1,201.0	1,204.9	1,204.9

Table 5-2 high growth low growth and medium growth BAU scenarios for Urban residential sector

Scenario	2021	2025	2030	2035	2040	2045	2050
High growth	5,771.8	5,999.6	6,234.8	6,408.1	6,513.8	6,548.6	6,548.6
Low growth	5,771.8	5,981.3	6,192.0	6,339.7	6,419.7	6,429.4	6,429.4
Medium growth	5,771.8	5,989.5	6,211.1	6,370.2	6,461.6	6,482.4	6,482.4

Table 5-3 high growth low growth and medium growth BAU scenarios for total residential sector

Scenario	2021	2025	2030	2035	2040	2045	2050
High growth	6,844.6	7,114.8	7,393.7	7,599.1	7,724.5	7,765.8	7,765.8
Low growth	6,844.6	7,093.0	7,342.9	7,518.1	7,613.0	7,624.4	7,624.4
Medium growth	6,844.6	7,102.7	7,365.6	7,554.2	7,662.6	7,687.3	7,687.3

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