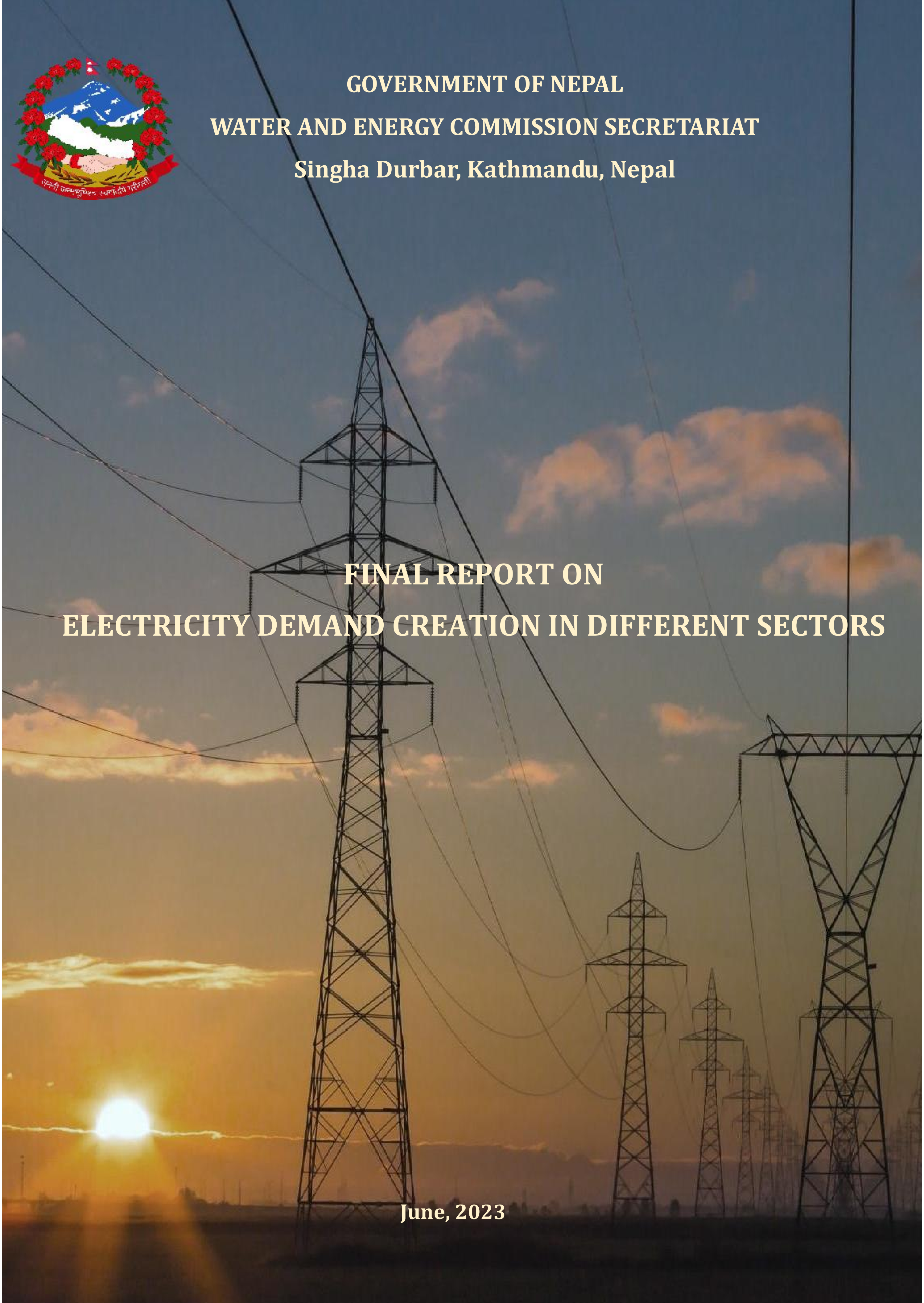
GOVERNMENT OF NEPAL

WATER AND ENERGY COMMISSION SECRETARIAT

Singha Durbar, Kathmandu, Nepal



FINAL REPORT ON
ELECTRICITY DEMAND CREATION IN DIFFERENT SECTORS

June, 2023

EXECUTIVE SUMMARY

Nepal has achieved impressive progress in expanding its electricity generation capacity, experiencing remarkable growth rates in recent times. This surge in electricity production has been accompanied by a noticeable rise in electricity consumption across various sectors of the economy. However, as electricity generation continues to outpace consumption, there arises a need to create more demand for electricity. The Government of Nepal acknowledges the potential benefits of boosting domestic electricity consumption, which aligns with its commitment to achieving net-zero emissions by 2045. To address this, the "Electricity Demand Creation in Different Sectors" project aims to identify strategic interventions that support national objectives, optimize energy resources, and promote a more resilient and electrified future." This report presents a comprehensive analysis of Nepal's energy and electricity demand forecasting, with a particular focus on electricity demand creation in different economic sectors: agricultural, commercial, industrial, residential, transport, and construction & mining. The Energy Modelling approach, utilizing the LEAP tool, was employed to forecast energy consumption patterns by meticulously analyzing individual end-users and aggregating subsectors within each sector. Four distinct scenarios, namely Low Growth, Business-As-Usual (BAU), High Growth, and Electrification were developed to assess the impact of various macroeconomic factors on energy demand variations. As of 2021, Nepal's total energy consumption reached 625.6 PJ. The projections for 2045 showcase varying scenarios: low growth predicts 950.9 PJ, BAU forecasts 1603.8 PJ, electrification (Renewable Energy) estimates 940.5 PJ and high growth anticipates 2881.6 PJ. These projections correspond to Compound Annual Growth Rates (CAGR) of 1.45%, 3.30%, 1.42%, and 5.41%, respectively. The electrification scenario stands out for its transformative impact, aiming to reduce total energy demand by 1.7 times compared to BAU. By 2050, electricity is projected to account for 80.7% of total energy demand, a significant increase from the mere 4.2% share in 2021.

Agricultural Sector

In the agricultural sector, electrification efforts are directed toward achieving 100% electric water pumping by 2050. The transition to electric water pumps is projected to create an additional electricity demand of 18.31 GWh by 2030, 366.48 GWh by 2040, and 1168.50 GWh by 2050. The financial analysis reveals that investments in electric water pumps are highly profitable, with payback periods ranging from 3.45 to 6 years, depending on the level of subsidies. The internal rate of return (IRR) surpasses the discount rate of 12%, signifying the profitability of this venture.

Commercial Sector

The commercial sector experiences remarkable electricity demand growth, especially in the commercial segment. Under the electrification scenario, commercial electric cooking is projected to create an additional electricity demand of 332 GWh by 2030, 4,700 GWh by 2040, and 20,052 GWh by 2050. The financial analysis indicates favorable economic returns, making the adoption of electric cooking technologies an attractive option. The payback period for electric cooking is calculated to be 1.52 to 2.36 years, considering various levels of subsidies. The IRR for all cases involving subsidies exceeds 40%, indicating its economic favorability.

Industrial Sector

In the industrial sector, electrification efforts are set to increase electricity demand significantly, primarily driven by electric boiler and furnace adoption. The financial analysis for electric boilers and furnaces shows positive returns, making these investments economically viable. The payback periods for electric boilers and furnaces range from 4.35 to 8.66 years, depending on the level of subsidies, and the IRR for all cases involving subsidies exceeds the discount rate.

Residential Sector

The residential sector's electrification scenario targets electric cooking, projected to create additional electricity demand of 0.144 TWh by 2030, 4.322 TWh by 2040, and 11.018 TWh by 2045. The payback period for electric cooking ranges from 1.29 to 2.36 years, depending on the level of subsidies, and IRR exceeds 40%.

Transport Sector

The transport sector presents a significant opportunity for electricity demand growth through the transition to electric vehicles. The electrification scenario envisions public and private transport becoming fully electric by 2050, creating additional electricity demand of 2,510 GWh and 6,289 GWh, respectively. The financial analysis indicates that electric buses, cars, and two-wheelers are economically viable investments, especially with reduced tax rates. The payback periods for electric vehicles range from 3.14 to 6.04 years, depending on the vehicle type and level of subsidies, and the IRR for all cases involving subsidies exceeds the discount rate.

Construction and Mining Sector

In the construction and mining sectors, electrification efforts are expected to drive notable electricity demand growth, with a CAGR ranging from 18.38% to 26.94% from 2021 to 2050. The focus on adopting electric equipment will play a crucial role in meeting rising electricity demand and achieving a sustainable and efficient future.

The energy model and electrification scenarios provided valuable insights for identifying opportunities and interventions to create electricity demand. The transformative effects of electrification are evident in reducing overall energy demand while significantly increasing electricity consumption. Moreover, the financial viability of electrification initiatives for different priority end uses strengthened their potential impact and attractiveness as investments for a more sustainable and resilient energy future.

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ACRONYMS AND ABBREVIATIONS

AEPC	Alternative Energy Promotion Centre
BAU	Business as Usual
C & M	Construction and Mining
CAAN	Civil Aviation Authority of Nepal
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CBS	Central Bureau of Statistics
CCS	Carbon Capture and Storage
Ckt.km	Circuit Kilometers
CO_2	Carbon Dioxide
DC	Direct Current
DoC	Department of Commerce
DoED	Department of Electricity Development
DoTM	Department of Transport Management
ERC	Electricity Regulatory Commission
EV	Electrical Vehicle
GDP	Gross Domestic Product
GoN	Government of Nepal
GVA	Gross Value Added
GWh	Gigawatt House
HDI	Human Development Index
IPP	Independent Power Producers
IRR	Internal rate of Return
kV	Kilo Volts
LEAP	Low Emission Analysis Platform
MoALD	Ministry of Agriculture and Livestock Development
MoEWRI	Ministry of Energy, Water Resources, and Irrigation
MoF	Ministry of Finance
MoFE	Ministry of Forest and Environment
MoICS	Ministry of Industry, Commerce and Supplies
MoPIT	Ministry of Physical Infrastructure and Transport
MVA	Mega Volt Ampere
MW	Mega Watt

NDC	Nationally Determined Contribution
NEA	Nepal Electricity Authority
NOC	Nepal Oil Corporation
NPR	Nepalese Rupee
NZE	Net Zero Emission
OPEX	Operational Expenditure
RE	Renewable Energy
SDG	Sustainable Development Goals
SNDC	Second Nationally Determined Contribution
TEC	Total Energy Consumption
TWh	Terawatt Hours
UN	United Nations
WECS	Water and Energy Commission Secretariat

CHAPTER ONE: INTRODUCTION

1.1 Background

Water and Energy Commission Secretariat is a governmental agency with the primary responsibility to assist Government of Nepal and different ministries relating to Water Resources and Energy in the formulation of policies and planning of projects in the water and energy resources sector. It has previously published different documents highlighting the energy consumption and supply status of different along with forecasting the energy demand in different scenarios. Some of these documents are Nepal's Energy Sector Vision 2050 A.D., Electricity Demand Forecast Report (2014-2040), Energy Consumption and Supply Situation in Federal System of Nepal (Province 1, Madhesh Province and Bagmati Province) etc. All these reports highlight the necessity to shift towards electricity for the enhancement in the energy security in different economic sector.

With the increase in generation of electricity, the country has finally reached a stage where it has been able to export electricity to neighboring countries like India especially in the wet season. In the year 2021/22, the government has exported 493.61 GWh of energy. The country has further set the plans for increasing the generation of electricity in the upcoming years and increasing the cross-border electricity trade. Despite the electricity imports, in the overall energy scenario the country is still facing huge losses owing to the large imports of petroleum products. In the first eleven months of the year 2021/22, the country has imported more than NPR 292 million worth of petroleum product. Further the country has planned to increase the specific electricity consumption from 295.91 kWh /capita in 2021/22 to 1,500 kWh/capita by 2030. The increase in the per capita electricity consumption requires detailed assessment in different economic sector to identify the electricity demand and its penetration.

Keeping up with the necessity to increase the electricity demand in Nepal, WECS has developed in terms of reference for *"Electricity Demand Creation in Different Sectors"* with the aim to develop the short-, medium- and long-term plans that need to be implemented for creating more domestic electricity demand.

1.2 Objective

The main objective of the study is to identify the options and interventions for increasing the electricity demand in different economic sectors. The other specific objectives are as follows:

- To assess the current use of electricity in different economic sectors and to identify the different electrical energy intensive demand in different economic sectors (Industrial, Commercial, Residential, Transport, Agriculture, Construction & Mining and Others.)

- To identify the growth of import of different electrical appliances and equipment in last five years.
- To quantify the potential electricity demand growth.
- To identify the bottlenecks for electricity demand growth.
- To develop policy brief and implementation plan for increasing/ creating electricity demand in short, medium and long terms.
- To identify the options and interventions for increasing the electricity demand in different economic sectors.

1.3 Rationale

In recent years, Nepal has made significant strides in expanding its electricity generation capacity, exhibiting a commendable upward trend. The compound annual growth rate (CAGR) for electricity generation over the last five years stands at an impressive 16.29%, while the ten-year CAGR remains robust at 10.63%. Notably, the growth in electricity generation last year alone reached a remarkable 57.50%. This positive development is a testament to Nepal's dedicated efforts in harnessing its abundant water and energy resources to meet the rising energy demands of the nation. Simultaneously, electricity consumption in Nepal has also been on the rise, displaying a notable average annual growth rate. With an average annual increase of 27.39% in electricity consumption, along with 10.87% and 11.43% CAGR for the last five and ten years, respectively, the expanding needs of diverse economic sectors underscore the nation's overall development. While both electricity generation and consumption experience substantial upward trajectories, it is evident that electricity generation's growth surpasses that of electricity consumption. This indicates that there will likely be a point in the future when electricity supply may outstrip the existing demand. In light of this scenario, it becomes imperative to focus on electricity demand creation to optimize the increased generation capacity and ensure the long-term sustainability of Nepal's energy sector.

The necessity for electricity demand creation goes beyond addressing the growing surplus in electricity. It is also driven by the Government of Nepal's recognition of the potential benefits of bolstering domestic electricity consumption. In line with this vision, various energy policies have been outlined, and long-term plans have been formulated, including the Nationally Determined Contributions (NDCs) and a commitment to achieve net-zero emissions by 2045. In pursuit of this goal, promoting and incentivizing electrification in different sectors emerges as a critical strategy. These initiatives underscore the significance of enhancing electricity demand across diverse economic sectors, thereby achieving energy security, sustainability, and fostering overall economic growth. Given these pivotal developments and the projected trajectory of electricity generation and consumption, the imperative for electricity demand creation is evident. This project, "Electricity Demand Creation in Different

Sectors," seeks to identify and implement strategic interventions that align with national objectives. With this comprehensive endeavor, Nepal aims to optimize its energy resources, reduce dependency on imported fossil fuels, and pave the way for a more resilient and electrified future. As this report is intended for submission to the Government of Nepal, it underscores the significance of informed policy decisions and outlines pathways for achieving the nation's energy aspirations in a sustainable and efficient manner.

1.4 Policy Context

1.4.1 National Policies

The Government of Nepal along with different development partners has prepared various reports and documents for the promotion electricity and electricity-based technologies in Nepal. Following are some of plan and policies related to electricity demand creation:

Plan/Policies	Targets and Goals
Sustainable Development Goals (SDGs)	• Increase in proportion of population with access to electricity to 99% in 2030 • Increase in per capita electricity consumption to 1,027 kWh in 2025 and 1,500 kWh in 2030 • Increase in installed capacity of hydropower from 782 MW to 10,260 MW in 2025 and 15,000 MW in 2030 • Increase in share of electric vehicle in public transport from 1% in 2020 to 35% in 2025 and 50% in 2050
15th Periodic Plan	• Increase the per capita electricity consumption from 245 kWh in 2018/19 to 700 kWh in 2023/24
Second Nationally Determined Contribution, 2020	• By 2030, expand clean energy generation from approximately 1400 MW to 15000 MW of which 5-10% will be generated from mini and micro hydropower, solar, wind and bioenergy. Of this, 5,000 MW is an unconditional target. The remainder is dependent upon the provision of funding by the international community. • In 2025, sales of electric vehicle will be 25% of all private passenger vehicle sales, comprising of two-wheeler and 20% of all four-wheeler public passenger vehicle sales excluding e-rickshaws and electric tempos. • By 2030, electric vehicles sales will increase to cover 90% of all private passenger (two wheelers and 60% of

Plan/Policies	Targets and Goals
	four-wheeler public passenger vehicle excluding e-rickshaw and e-tempos. • By 2030, develop 200 km of electric rail network to use as public travelling as well as freight transportation.
National Energy Efficiency Strategy	• Double energy efficiency improvement rate from 0.84% in 2000-2015 to 1.68% in year 2030.
Renewable Energy Subsidy Policy	• Provisions for electrification of country by different renewable energy sources like biogas, solar and wind power generation etc.
Nepal Government's Plan & Policies, 2080	• Production and use of electric vehicles will be encouraged to reduce dependence on petroleum products. Carbon emissions will be reduced by using renewable and clean energy in the transport sector. • Access to energy for all citizens will be ensured. Electricity will be connected to each household within two years. Free electricity will be provided to consumers consuming up to 50 units per month in rainy season and up to 30 units in winter. Cooking gas will be gradually replaced by electricity. • Electricity generation, transmission and distribution will be promoted in a coordinated way. Transmission and distribution system will be reinforced and expanded • New infrastructure will be constructed in order to promote internal consumption of electricity produced in the country. • Underground electricity transmission system will be expanded in major cities. All renewable energy products will be connected to national transmission line.
Nepal's Energy Sector Vision 2050 A.D.	The following electricity generation plan were suggested by Energy Sector Vision 2050 AD: • 11500 MW in 2030 • 31000 MW in 2050 All these plans are made for GDP share of energy sector as 2.4%.

Plan/Policies	Targets and Goals
Environment-friendly Vehicle and Transport Policy (2014)	• Development and promotion and extension of environment-friendly and electric vehicles (EV) and transportation.
Hydropower Development Policy 1992, Hydropower Development Policy 2001, Water Resources Act 1992 and Electricity Act 1992	• Focuses on bringing foreign private sector investment in electricity development
Hydropower Development Policy (2001)	• Policies for taking resources from the private sector, government, and bilateral and regional cooperation to develop hydroelectric plants.
Industrial Policy (2011)	• Provision for No or lower tax for Industry using completely electricity as fuel
The current situation and future road map of Water, Energy, and Irrigation (2019/20)	• Specify electricity consumption per consumer goal of 700 kWh per consumer within the first 5 years and 1500 kWh in the next 10 years by changing other sources of energy to electricity. • East-West High-Tension transmission (400 kV) line development • Development of policies for international trade of electricity

1.4.2 International Policies

The various reports and documents developed for the promotion electricity and electricity-based technologies in regional counties and by global institutions were also reviewed. Following are some of plan and policies related to electricity demand creation.

Country	Plan/Policies	Targets and Goals
India	Nationally Determined Contributions (NDC)	• 50% of total electricity generation by clean electricity by 2030
Pakistan	NDC Plan	• 30% EVs by 2030 and 90% electric car by 2040 • Sell 50% of electric two- and three-wheelers 2030
	Alternative and Renewable Energy Policy (AERP)	• 20%(20×25) and 30% (30×30) of total generation from RE technologies by 2025 and 2030 respectively
Sri Lanka	National Energy Policy and Strategies	• Electrify functional railways • Installation of 25 new DC quick charging stations by CEB (Ceylon Electricity Board)
Bhutan	Nationally Determined Contribution (NDC)	• 20% of public and 10% of private vehicles to be electric or renewable energy-based by 2025
UN	SDG 7	• Universal Access to Electricity: One of the key objectives of SDG 7 is to ensure universal access to affordable and reliable electricity. This involves extending electricity grids to remote and underserved areas.
	SDG 13	• Net Zero Emission (NZE) 2050: Several countries and organizations have committed to achieving net-zero greenhouse gas emissions by 2050.NZE Focuses on renewable energy adoption like electrification.

CHAPTER TWO: ELECTRICITY INFRASTRUCTURE & ACCESS

2.1 Electricity Generation

As of NEA Annual Report 2021-2022, Nepal's total electricity availability reached 11,064 GWh. Among this supply, 29.4% (3,259 GWh) was generated by the Nepal Electricity Authority (NEA) itself, while 17.8% (1,976 GWh) was purchased from subsidiaries, and 38.7% (4,286 GWh) was procured from Independent Power Producers (IPPs). Additionally, 13.9% (1,543 GWh) was imported from India. The electricity generation attributed to Nepal itself amounted to 9,521 GWh. Independent Power Producers (IPPs) currently contribute around 1,021 MW of electricity from various hydroelectric plants and 33 MW from solar plants. The IPP sector is actively constructing additional electric plants across Nepal, with an estimated cumulative power generation capacity of about 2,775 MW from all hydroelectric plants under construction and 58 MW from solar plants.

With NEA, there are different hydroelectric plants, alongside several small isolated and non-isolated hydropower plants, generating a total of approximately 583 MW of electricity. Isolated hydropower plants produce around 4.5 MW, catering to local areas without being connected to the national grid. Moreover, the NEA operates solar plants with a combined generation capacity of about 22 MW.NEA's subsidiaries currently operate various hydropower plants, contributing to a net electricity capacity of 478 MW. Several NEA subsidiary hydropower plants are under construction, with an expected total electricity generation of 483 MW once completed. Thus, the total electricity generation anticipated from NEA subsidiaries, after successfully finishing all ongoing construction projects, would be approximately 960 MW.

Table 2-1: Electricity Generation Status of Nepal

Particulars	Power plant capacity (MW)			
	Operational	Under construction	Planned with survey license	Government project bank
Hydropower	2,198.80	8,837.90	10,912.90	12,096.30
Solar	55.00	58.00		
Thermal	53.00			
Total	2,306.80	8,895.90	8,895.90	8,895.90

Source: NEA, DOED, Jun 02, 2023

Furthermore, several proposed hydropower projects in different locations have the potential to generate around 3,219 MW of electricity if successfully developed and operated. In summary, the current total electricity generation capacity in Nepal, including IPPs, NEA, and its subsidiaries, stands at about 2,190 MW. With ongoing construction and proposed projects, the total capacity is projected to exceed 8,500 MW in the near future. These efforts underscore Nepal's commitment to diversifying energy sources, expanding its energy generation capacity, and meeting the rising energy demands while enhancing energy security.

2.2 Electricity Transmission & Distribution

In recent years, Nepal has experienced substantial growth in its transmission line network, witnessing an average annual increment rate of 10.7% over the last 8 years. By the fiscal year 2021/2022, the country's transmission lines with a voltage level of 66 kV or higher had reached a total length of 5,329 circuit kilometers (ckt. km), nearly doubling over this period. During the preceding year, 455 ckt. km of transmission lines were added, marking a significant 9.3% increase compared to the previous fiscal year. The transmission line loss in Nepal for the fiscal year 2077/078 was recorded at approximately 4.64%, showing a slight increase from the previous year

Currently, there are ongoing construction projects for 3,114 ckt. km of transmission lines with a total capacity of 7,857 MVA, including transmission lines with voltage levels of 132 kV, 220 kV, and 400 kV. Additionally, plans and proposals are in place for the construction of more substations with a total capacity of 10,463 MVA, along with transmission lines at voltage levels of 132 kV, 220 kV, and 400 kV.

As of the fiscal year 2021/2022, Nepal had 6,620 ckt. km, 44,840 ckt. km, and 136,595 ckt. km of transmission lines with voltage levels of 33 kV, 11 kV, and 0.4/0.23 kV, respectively. The number of distribution transformers also increased by 5.9%, reaching a total of 39,361 distribution transformers with a capacity of 3,845 MVA.

Table 2-2: Electricity Transmission Line (Under construction, Planned & Purposed)

S.N.	Particulars	Voltage Level (kV)	Transmission Directorate (Ckt.km)	Project Management Directorate (ckt.km)	Total (ckt.km)
1.	Under construction Transmission Line	132 kV	1158	272	1430
		220 kV	438	492	930
		400 kV	576	178	754
Total (Circuit km)			**2172**	**942**	**3114**
2.	Planned and Proposed Transmission Line	132 kV	1150	320	1470
		220 kV	251	0	251
		400 kV	1090	1920	3010
Total (Circuit km)			**2491**	**2240**	**4731**

The Project Management Directorate (PMD) is overseeing various construction projects, including the development of a 256 MVA capacity 33/11 kV substation, overhead and underground distribution lines, and conducting feasibility studies for additional transmission lines and substations to meet future electricity demands.

According to the NEA Annual Report 2021-2022, Nepal's electrification status of local levels (regions) indicates that 63.3% (476 out of 753) were substantially electrified, 32.1% (242) were partially electrified, and 4.6% (35) were yet to be electrified. Additionally, out of 77 districts in Nepal, 54.5% (42) were substantially electrified.

Table 2-3: Electricity Distribution Substation (Under construction, Planned, Purposed)

S.N.	Description	Transmission Directorate (MVA)	Project Management Directorate (MVA)	Total (MVA)
1.	Under construction	5166.50	2691.00	7857.50
2.	Planned and proposed	4553.00	5910.00	10463.00

2.3 Electricity tariff

In recent years, the electricity generation has surpassed the domestic demand and it has been expected that the generation and demand gap will grow further in future. Therefore, the effective demand creation is the main challenge that the country has to face in future. In order to address this challenge, NEA has begun to provide affordable tariff rates to the industrial, residential and commercial sectors.

The Electricity Regulatory Commission (ERC) in Nepal has implemented several measures to stimulate electricity consumption in different sectors. For domestic consumers involved in electric cooking, the minimum charge for certain consumption levels has been reduced, depending on their monthly consumption. This move aims to encourage more households to shift to electric cooking appliances, provided there is a reliable and quality supply of electricity. Furthermore, the irrigation sector tariff has been significantly reduced to incentivize farmers to use electricity for irrigation, aiming to boost agricultural production and improve farmers' livelihoods. In the industrial sector, the ERC has refrained from increasing the demand charge by Rs 100 per-kVA per month, keeping it unchanged to stimulate industrial power consumption and potentially lead to reduced retail prices for industrial products. These tariff adjustments are part of the government's strategy to increase overall electricity consumption and achieve sustainable energy goals in the country.

CHAPTER THREE: ELECTRICITY USE IN NEPAL

3.1 Energy & Electricity Demand

In the past, Nepal's energy consumption heavily relied on traditional fuels. However, with advancements in technology and the implementation of government policies and plans, the country is progressively transitioning towards the utilization of commercial fuels and renewable energy sources. As a result of these efforts, the overall energy consumption in Nepal has significantly risen, reaching 626 PJ in 2021 compared to 401 PJ in 2008. During the same period, electricity consumption in Nepal has shown remarkable growth, increasing from 8.13 PJ to 26.37 PJ. The distribution of energy consumption across various fuel types is depicted in Figure 3-1.

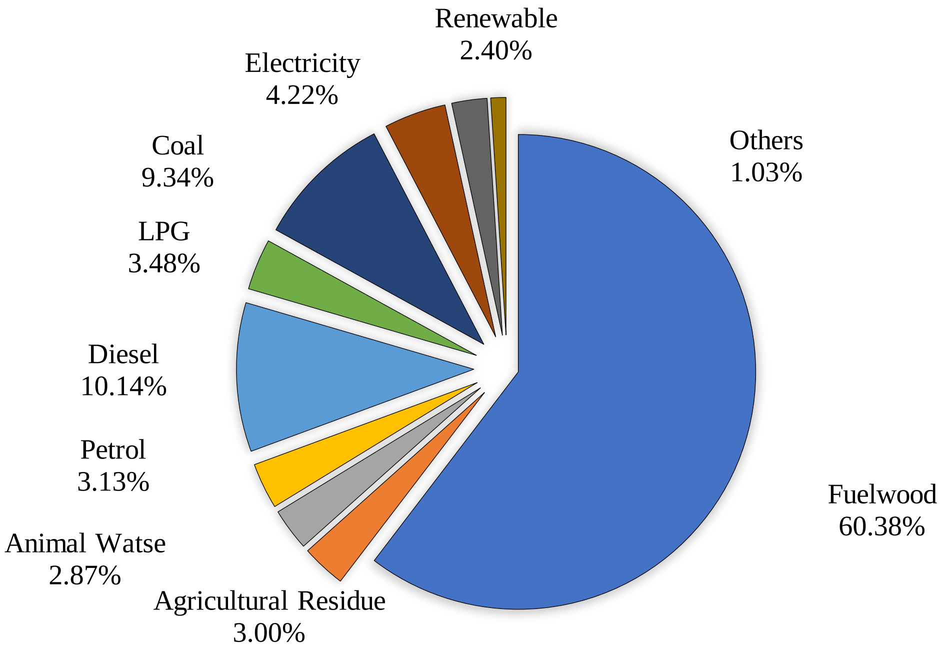

Figure 3-1: Energy consumption fuel wise

Likewise, the distribution of sectoral energy consumption has undergone a notable shift in Nepal. Back in 2008, the residential sector dominated the energy use, accounting for over 89% of the total consumption, mainly attributed to biomass burning practices. However, in recent years, there has been a substantial increase in energy consumption within the industrial and commercial sectors. By the fiscal year 2021, the energy consumption in the residential sector has decreased to 18.3%, reflecting a significant decline from its previous dominant position. In contrast, the industrial and commercial sectors have witnessed substantial growth in energy consumption, each contributing 18.3% to the overall energy consumption. Additionally, the transport sector's energy consumption has reached 9.0%, indicating its increasing role in the country's energy landscape. This shift in sectoral energy consumption is illustrated in Figure 3-2, which highlights the evolving pattern of energy utilization across the residential, industrial, commercial, and transport sectors. The changing landscape signifies the diversification of energy sources and consumption patterns in Nepal, driven by technological advancements, policy interventions, and the growing awareness of the importance of sustainable energy practices.

Moreover, the efficiency of fuel use within the sectors has witnessed significant improvements. In the past, electricity consumption in Nepal primarily revolved around lighting purposes and small electrical appliances. However, the scenario has evolved over time, and electricity has now permeated large energy-intensive equipment, exemplified by its rising share of consumption in the industrial and commercial sectors.

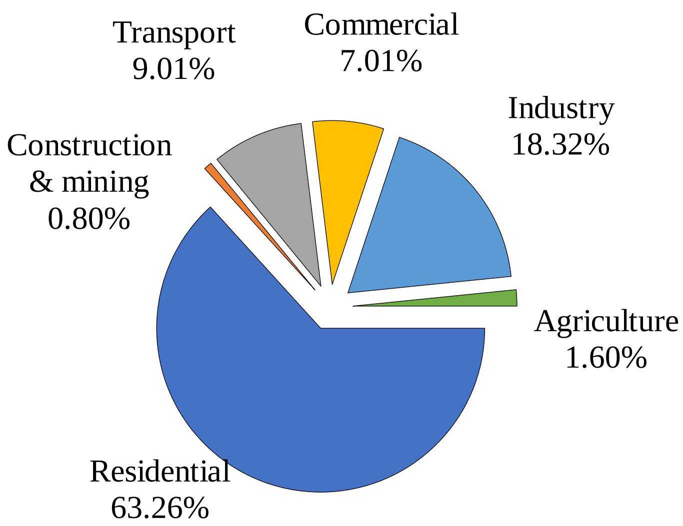

Figure 3-2: Energy consumption sector wise

Table 3-1 presents a comprehensive overview of electricity consumption in various sectors for the year 2021. The data showcases the increased adoption of electricity as a preferred energy source for powering industrial and commercial operations. This transition towards electricity usage in energy-intensive applications is a testament to the country's efforts in optimizing energy consumption patterns and embracing more efficient and sustainable practices within these sectors. The shift towards electricity in these industries aligns with Nepal's drive towards energy diversification and a cleaner, more environmentally friendly energy landscape.

Table 3-1: Sectoral Electricity Consumption

Economic sector	Total Electricity consumed (GWh)
Residential	3,241.19
Commercial	1,055.45
Agricultural	202.69
Industry	2,823.20
Transportation	1.94
Construction & Mining	1.47

3.2 Electrical Appliances

Nepal utilizes a diverse range of electricity-based technologies and appliances in different economic sectors to meet specific demands. In agriculture, common equipment like pumps, fertilizer production, and crop drying rely on electricity. Commercial buildings extensively use electricity-intensive technologies such as lighting, refrigerators, ventilation, cooling systems, computers, office equipment, cooking appliances, and space heating. Electricity consumption patterns vary across industries, with electric arc furnaces, cement kilns, paper mills, and chemical plants having varying power requirements. Metalworking shops typically have lower electricity consumption capacity compared to other industries. Electric furnaces, pumps, compressors, motors, and boilers are commonly used in industrial processes. In the residential sector, electricity-intensive technologies include heating, cooling (including cooking), water heating, lighting, appliances, TVs, and computers. The transportation sector also relies on electricity for various vehicles and machines, such as motorcycles, mopeds, scooters, tempos, e-rickshaws, jeeps, vans, cars, buses, diesel-electric hybrid locomotives, cable cars, and motorboats. The construction and mining sector also use electricity-intensive equipment like excavators and cranes. Some electrical technologies, such as pumps, motors, refrigerators, and air conditioning systems, have applications across multiple sectors, highlighting their importance in improving overall energy efficiency in Nepal's economy.

3.2.1 Baseline for Electrical Appliances

Various electrical appliances require specific power supply characteristics, including different current, voltage levels, and frequency of electric power. To accommodate these varying requirements, different domestic wiring and fuse configurations are necessary. The following tables outline the minimum requirements for different technologies in terms of power, frequency, voltage, current, wire capacity, and fuse capacity. These specifications ensure the safe and efficient operation of each electrical appliance.

Table 3-2: Minimum Requirement for Different Electrical Technologies

<table>
<tr><th rowspan="2">Sector</th><th rowspan="2">Technologies</th><th colspan="5">Requirements</th></tr>
<tr><th>Voltage</th><th>Power</th><th>Current</th><th>Fuse</th><th>Wire Size</th></tr>
<tr><td>Residential</td><td>Washing machine, TV, Radio etc.</td><td rowspan="7">220 V</td><td rowspan="4">Below 1300 W</td><td rowspan="4">Below 6 A</td><td rowspan="4">6 A</td><td rowspan="4">2.5 sq.mm</td></tr>
<tr><td>Residential</td><td rowspan="2">Fan, Vacuum Cleaner, Refrigerator, Electric Heater</td></tr>
<tr><td>Commercial</td></tr>
<tr><td>Agricultural</td><td>Electric Corn Thresher</td></tr>
<tr><td>Commercial</td><td>Oven, Induction Heater, Water Heater</td><td rowspan="3">1300 - 3500 W</td><td rowspan="3">Below 16 A</td><td rowspan="3">16 A</td><td rowspan="3">2.5 sq. mm</td></tr>
<tr><td>Residential, Agricultural</td><td>Electric Pump</td></tr>
<tr><td>Agricultural</td><td>Chaff Cutter</td></tr>
</table>

Sector	Technologies	Requirements				
		Voltage	Power	Current	Fuse	Wire Size
Transport	Moped, Motorcycle, Scooter, Three-wheeler		3500 - 7000 kW	Below 32 A	32 A	4 sq. mm
Industries	Compressor, Pump, AC Motors					
Agricultural	Electric Power Tiller					
Agricultural	Combined Harvester	Dedicated Transformer and three phase lines required				
Industrial	Boiler, Compressor, AC Motors, Electric Furnace,					
Transport	Tractor, Electric Car, Jeep, Van, Micro, Three -Wheeler, Bus etc.					
Agricultural	Tractor					
Construction and Mining	Other Boring, Drilling Tools					

3.2.2 Growth of Electrical Appliances

Over the years, Nepal has been importing various electrical technologies to meet the growing demand for electricity and to improve the country's energy infrastructure. Upon examining the import records of various electric appliances from Department of Custom over the past five years, a notable and substantial growth is evident, marked by a robust Compound Annual Growth Rate (CAGR) surpassing 30%. Particularly, appliances such as ovens have exhibited an even higher CAGR of 74%, as indicated in Figure 3-3. This data reflects Nepal's society's rapid adoption of electrical technology and a strong inclination towards electricity as a preferred energy source.

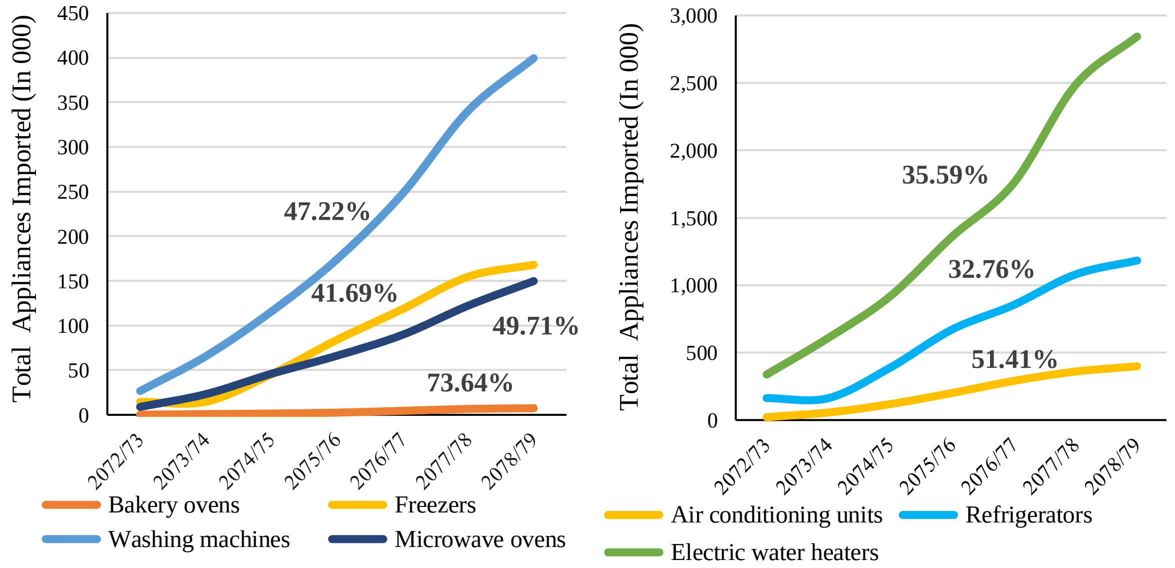

Figure 3-3: Growth of Import of Different Electrical Appliances

The increasing import trends in both electrical appliances and EV technologies underscore the nation's willingness to embrace modern and sustainable solutions. This shift not only aligns with global energy and environmental trends but also offers opportunities for economic growth and development in Nepal's evolving energy landscape. Policymakers and stakeholders can leverage this momentum to foster a thriving market for electrical technologies and electric vehicles while simultaneously promoting the establishment of robust infrastructure to support their widespread adoption.

3.3 Electricity Intensive Industry

Industries have a significant energy consumption, with electricity accounting for a considerable share. In Nepal, industrial energy and electricity demand was approximately 18.3% of the total energy consumption and 38.5% of the total electricity consumption in year 2021 similarly for year 2022 the share of electricity consumption by industrial sector is 36.9% (NEA). Given the high electricity consumption in industries, it is crucial to plan and identify electricity-intensive industries worldwide. Suggesting different electricity-intensive industries becomes essential to manage and meet the demand for electricity effectively.

Table 3-3: Loads in different Industry

Types of industry	Estimated load
Fertilizers industry	Up to 500 MW
Electric arc furnaces	up to 100 MW
Cement Kilns	up to 50 MW
Paper mills	up to 30 MW
Chemical plants (Except Fertilizer)	up to 20 MW
Metal working shops	up to 10 MW

3.3.1 Fertilizer Industry

3.3.1.1 Introduction

Production of nitrogenous fertilizers is the most energy-intensive process in the fertilizer industry. Ammonia serves as the fundamental chemical for manufacturing these fertilizers, with over 80% of global ammonia production dedicated to their production. The feedstock used for ammonia production includes natural gas, naphtha, and fuel oil, with coal-based units no longer viable due to economic constraints and high energy consumption. Among the feedstock options, natural gas-based fertilizers are the most energy-efficient, followed by naphtha-based fertilizers. To improve energy efficiency, major modernization measures have been implemented, such as two-stage concentration, more efficient trays in urea reactors, nutrient recovery from process effluents, recycling treated process condensate, and refurbishment or replacement of rotating machines. Most urea plants have energy consumption ranging from 5.25 to 6.0

Gcal per ton of urea. Out of the total energy consumed at the designated consumer plant boundary, the stoichiometric energy of 2.53 Gcal per ton of urea is contained within the urea product itself and is released as such.

3.3.1.2 Electricity Use in Fertilizer Industries

The adoption of electricity in industrial processes can offer significant efficiency advantages, especially in the application of heat pumps for low-temperature heat. It also presents a potential co-benefit by enabling industry electrification, which can help balance electricity grids and provide flexibility to grid operators. Various commercially available technologies can replace fossil fuels for heat demand, including electrode boilers, electrical resistance heating, heat pumps, steam recompression, and electric arc furnaces. These technologies have the potential to electrify the entire steam demand of industries, thereby potentially covering almost 30% of industrial CO_2 emissions. However, certain challenges remain for the widespread deployment of electrification technologies. The main barrier is the economic aspect, as the operational expenditure (OPEX) are currently 2-3 times higher for electrification compared to conventional methods (EC, 2019). Additionally, significant investments are required, ranging from 0.165-0.208 Million USD/MW for an electric boiler and up to 3.84-5.5 Million USD/MW for a furnace. Despite the challenges, electrification has the potential to replace production processes or parts thereof in various industries, such as electrowinning of iron through electrolysis of iron ore. The majority of industrial processes can eventually be electrified, reducing the need for molecules as fuel and shifting towards using them as feedstock. However, infrastructural challenges in the electricity grid need to be addressed to support the increased industrial demand for electricity, which could impact the business case if industrial users have to bear the costs of reinforcing the grid.

On the positive side, electrification can offer several benefits to industries, including improved process controllability, product quality, and reduced maintenance requirements (Policy Department of Economic, European Parliament, 2020). Despite some challenges, embracing electrification in industrial processes holds significant potential for enhancing energy efficiency and reducing carbon emissions in the long run.

3.3.1.3 Production of Urea Using Water Electrolysis

Hydrogen Production from the Electrolysis of Water: Electricity from hydropower, needs to be converted into DC power via a rectifier which then splits the water into hydrogen and oxygen in a fuel cell with electrolytes (mostly alkaline electrolytes such as KOH & NaOH). The hydrogen that is produced is dried and stored in a tank. The oxygen is sent into the atmosphere. The system does not capture oxygen gas but capturing the highly pure oxygen gas is a possibility, allowing it to be supplied as a by-product. The plant is expected to function at least 23 hours a day and at a maximum of 24 hours a day over 330 days in a year.

Production of Urea: This process involves the reaction of hydrogen and nitrogen under high temperatures and pressures with an iron-based catalyst. The source of nitrogen is always air. The manufacturing of urea is possible using water electrolysis. However, to manufacture urea, water electrolysis alone will not suffice as the urea is manufactured through a combination of ammonia and carbon dioxide. In the water electrolysis process, there is no carbon compound unlike in other technologies that uses natural gas and coal gasification where the CO_2 is generated as part of the process and is consumed to manufacture the urea. Hence, there is a challenge in sourcing carbon dioxide. A possible solution could be the recovery of carbon dioxide from nearby flue gases of power plants, cement plants, or similar such process units. Such a process is called carbon capture and storage (CCS). Carbon Capture and Storage (CCS): The worldwide installed capacity of CCS is around 40 metric tons per annum. Typically, CCS design and construction costs are in the hundreds of millions, sometimes billions, of US dollars. Flue gases from cement kilns are good candidates for CCS. Their typical CO_2 concentrations are around 14-33 percent higher than from conventional coal-fired combustion. To manufacture 2,125 metric ton per day of urea, 1,573 metric ton per day of CO_2 is required (i.e., for 1 metric ton per day of urea, 0.7402 metric ton per day of CO_2 is required). The total CO_2 emission from cement productions in Nepal for 2019 was estimated at 3.45 ± 0.50 million metric tons (Thakuri, et. al, 2021). A study was conducted by Kathmandu University for a system which was designed for 250,000 ton/year carbon capture, and it was found that for 700,000 tons of urea, 1,200,000 metric tons per year CO_2 capture is needed. The cost of capturing is USD 0.086 per kg of CO_2 but cost will be lower when done at a larger scale. The data that was used for simulation comprised of 15 percent CO_2 by weight, but usually cement flue gas has 25-30 percent CO_2.The annual demand for chemical fertilizers in Nepal was 700,000-800,000 metric tons in 2011/12 (Source: Nepal Economic, Agriculture and Trade Activity (NEAT)). The overall power requirement of an electrolysis bases power plant is the sum of the power requirements of the following: (Investment board, GoN, 2014)

- Electrolysis plant for hydrogen generation
- Air separation plant for nitrogen generation
- Carbon-dioxide capture plant for carbon dioxide generation
- Ammonia synthesis
- Urea synthesis

Electricity Requirement:

- To produce 1 metric ton of hydrogen, from electrolysis is in the range of 48,950 to 50,000 kWh of electricity.
- To produce 1 metric ton of Nitrogen from air separation requires 253 kWh of electricity.

- To produce 1 metric ton of Ammonia, energy consumption by Haber-Bosch process for synthesizing ammonia to produce a metric ton is about 12MWh. (i.e., 12000 kWh of electricity)
- To capture 1 metric ton of carbon dioxide, 500 kWh electricity is required.
- The electricity requirement to produce 1 metric ton of urea, from the reaction of NH_3 and CO_2 is 160 kWh. (IBN -2021)

The electricity consumption may vary depending upon the use of technologies. However, the cost of producing urea under water electrolysis method is higher than the cost of producing urea by natural gas method. But it could be one of the main energy inclusive industries in future to consume the produced hydroelectricity within Nepal. To produce 2125 mt. tons urea, per day 180,000 kWh electricity is required using natural gas and 10,800,000 kWh (About 450 MW per day) electricity is required using water electrolysis.

3.3.1.4 Chemical Fertilizers using Natural Gas vs. Water Electrolysis

The technology for using natural gas as a feedstock to produce urea is readily available in the international market and offers cost advantages in terms of capital expenditure and production costs. However, Nepal does not have access to natural gas domestically, requiring arrangements to import it from international markets, with India being a potential source through a cross-border pipeline. This importation can only be facilitated through the involvement of the private sector and the establishment of suitable policies and infrastructure for cross-border natural gas transportation. Natural gas is not only crucial as a feedstock for chemical fertilizers but also serves as an essential energy source and is considered a strategic commodity in the international market. The prices of such basic energy resources are generally more volatile compared to other commodities. As a result, the reliance on the international market for the import of natural gas and the uncertainty of its price fluctuations present significant challenges to the long-term sustainability of a chemical fertilizer plant that relies on natural gas as its feedstock.

3.3.2 Electricity Train

Nepal's Nationally Determined Contribution (NDC) for 2019 outlines an ambitious goal of adding 200 km of electric railway line by the year 2030. Based on data from the Indian Railways in 2019/2020, specific energy consumption for passenger service trains is recorded at 18.4 kWh per 1000 gross ton kilometers (GTKM), while for goods and service trains, it is 6.13 kWh per 1000 GTKM. Considering certain assumptions, such as the weight of the train, including passengers, being 400 tons and the weight of goods and service trains being 4000 tons, with passenger trains covering a daily distance of 800 km and freight trains covering 400 km, the estimated annual electricity requirement is around 1943.04 MWh for passenger trains and 3236.64 MWh for freight trains. By successfully installing the 200 km railway line by 2030, and introducing 4 passenger trains and 2 freight trains operating with the specified loads, the projected electricity consumption will align with the aforementioned estimates.

3.3.3 Non-Fired Brick

In 2018, approximately 1,349 brick kilns in Nepal utilized 504,750 tons of coal each year for brick production. However, in the context of non-fired bricks, there is no brick burning process involved, and consequently, there is no combustion of fossil fuels. Following data regarding production and requirement for a specific eco-friendly brick making machine called REX King (Indian Machine).

Table 3-4: Non Fired Brick Production

Hourly/Monthly Production Rate	Yearly Production Rate
3800/912000	11000000 (8 hr)
Monthly Required SS (kg)	Yearly Required SS kg
3.8 Tons	43.776 Tons
	SS: Soli and Stabilizers

The overall electric power consumption is 44 kW. For each eco-friendly non-fired brick, the electricity consumption is 0.0115789474 kWh. With a total production of 5.14 billion bricks from both biomass and fossil fuel sources, if replaced by non-fired brick the annual electricity consumption is expected to be 59,515 MWh.

3.4 Electricity Consumption & HDI

The per capita electricity consumption of a certain country is often regarded as an indicator of economic development and the degree of industrialization within a country. A high level of electricity consumption is typically associated with countries having advanced infrastructure, industries, and development. Electricity is a fundamental input for economic activities and productivity. Industries, businesses, and agriculture sectors heavily rely on electricity to power machinery, manufacturing processes, and irrigation systems. These factors, in addition, contribute to a higher HDI score. Table 3-5 shows information about The Group of Seven (G7) countries and their respective Human Development Index (HDI) and Electricity consumption per capita. HDI is a measure of a country's overall development and well-being. The HDI values range from 0 to 1, with higher values indicating higher levels of human development. According to the table, Germany has the highest HDI value of 0.942 among the listed countries followed by Canada at 0.936. Regarding electricity consumption per capita, Canada has the highest electricity consumption per capita followed by the United States. A higher electricity consumption per capita indicates that the country has a greater demand for electricity and its citizens tend to use more electrical energy on average. This can be indicative of a higher level of industrialization and economic development, as industries and manufacturing processes require substantial amounts of energy.

Table 3-5: HDI and Electricity consumption of G7 Counties, 2021

Countries	HDI	Electricity Consumption (kWh/Capita)
Canada	0.936	16,405.44
France	0.903	8,528.86
Germany	0.942	6,980.57
Italy	0.895	4,834.37
Japan	0.925	7,692.08
United Kingdom	0.929	4,565.32
United States	0.921	12,321.21

The electricity consumption per capita and HDI index of Nepal are increasing year by year. Nepal reached its highest HDI index of 0.602 in 2021, while the electricity consumption in the same year was 239.72. The electricity consumption of Nepal is too low in comparison to the G7 counties. Thus, efforts can be made to increase economic activities to increase electricity consumption. More electricity usage through the establishment of industries as well as the modernization of existing industries can considerably increase the HDI index and boost overall economic output. The comparison of the HDI index and electricity consumption per capita over different years is shown in Figure 3-5.

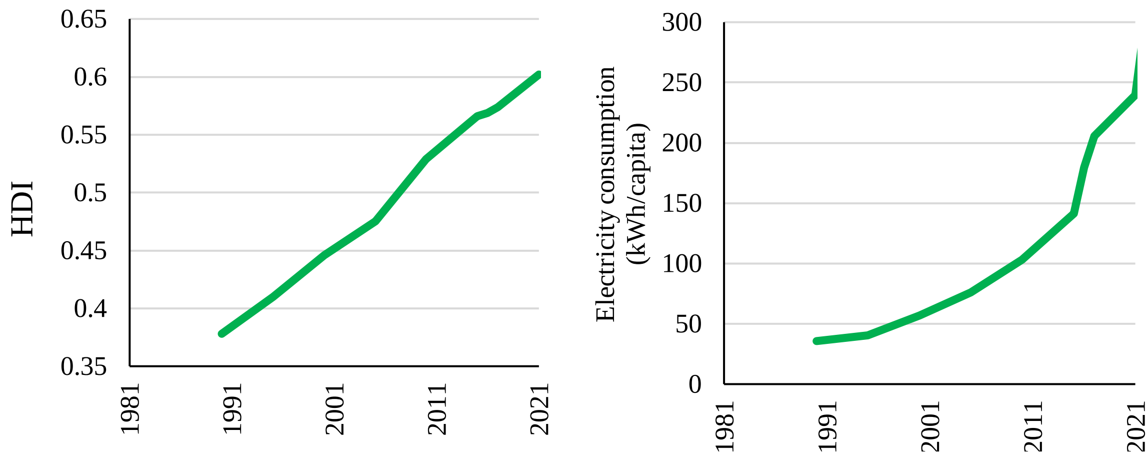

Figure 3-4: Comparison of HDI and Electricity consumption per capita

In Figure 3-5, a scatter plot displays the relationship between the Human Development Index (HDI) and Electricity consumption across various countries.

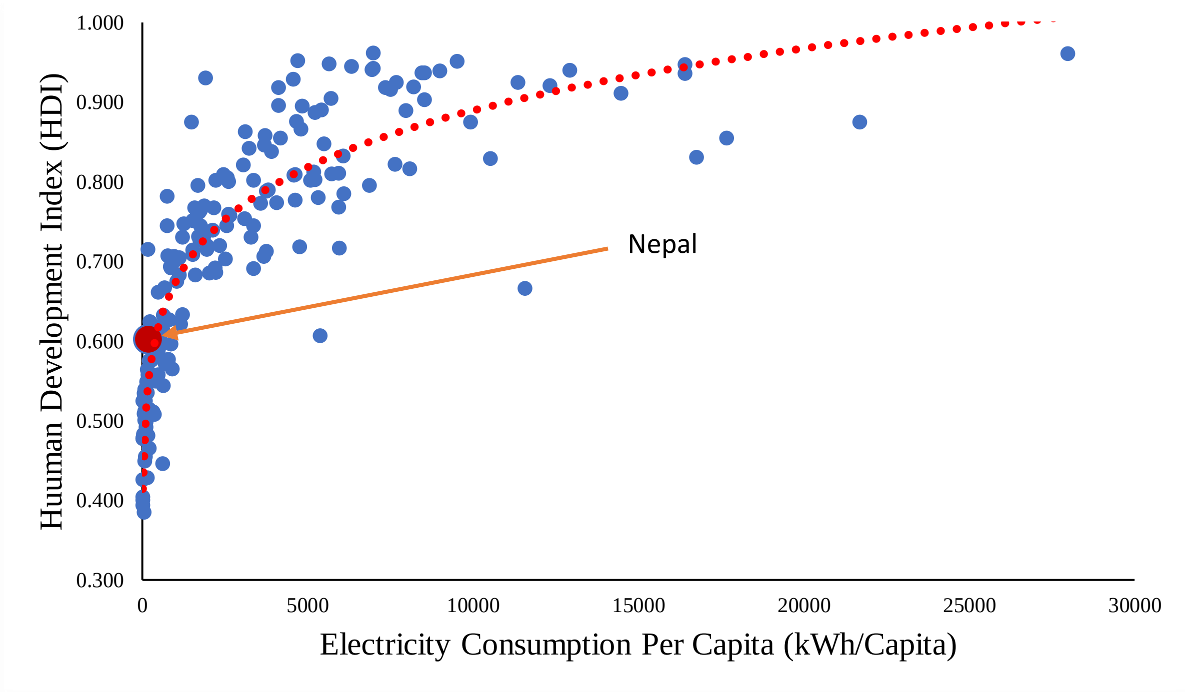

Figure 3-5: Electricity Consumption Per Capita vs. HDI

The picture clearly illustrates a strong correlation between electricity consumption and the level of human development. This indicates that as electricity consumption increases, there is a notable positive impact on the Human Development Index of these countries

CHAPTER FOUR: SCENARIO FRAMEWORK

Total electricity consumption in different sectors have been forecasted by using modeling tool. Baseline data for modeling has been taken based on policies and plans of different organizations. Final electricity demand for different scenarios has been determined.

4.1 Energy Modelling

The energy and electricity are forecasted by bottom-up energy forecasting approach. The bottom-up energy forecasting approach involves predicting energy and electricity consumption by analyzing individual end-users with various fuel types. By summing up the energy consumption of these individual units within a subsector, the total energy consumption for that subsector is determined.

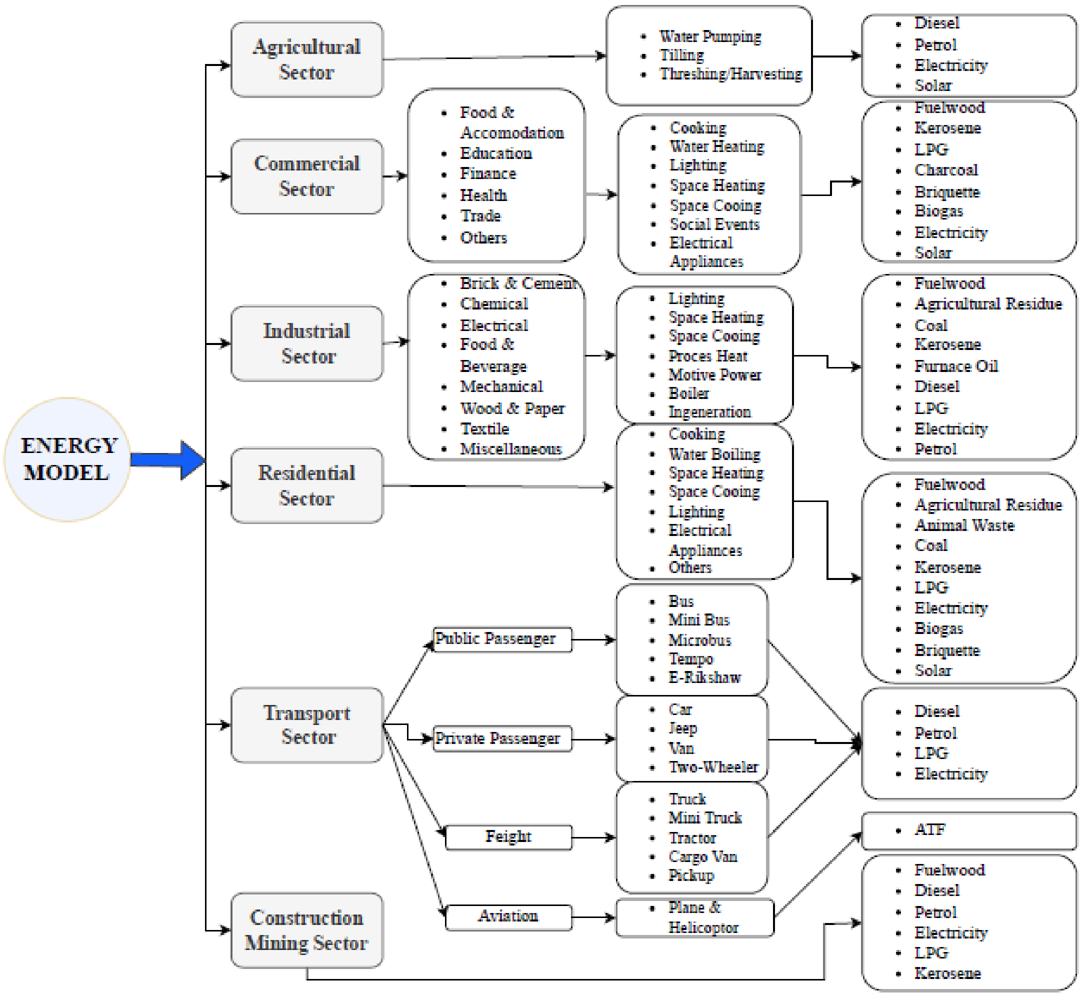

Figure 4-1: Energy Modelling Tree

The aggregation of subsector totals then provides the energy consumption for a sector, and when combined for all sectors, it yields the national total. This energy modeling approach offers a detailed understanding of energy consumption trends related to different resources and technologies. The energy model consists of six economic sectors (Agricultural, Commercial, Industrial, Residential, Transport, and Construction, Mining sector). The energy model uses a hierarchical (top-down) approach to divide each sector into subsectors. Within these subsectors, different end-use technologies are categorized, and each of these technologies is further classified based on the specific fuels they use.

The energy model utilized diverse input parameters as baseline information, introduced for a base year 2021. Additionally, growth parameters are incorporated to introduce different scenarios. Upon launching the model, it generated energy and electricity demand projection results for various scenarios by 2050.

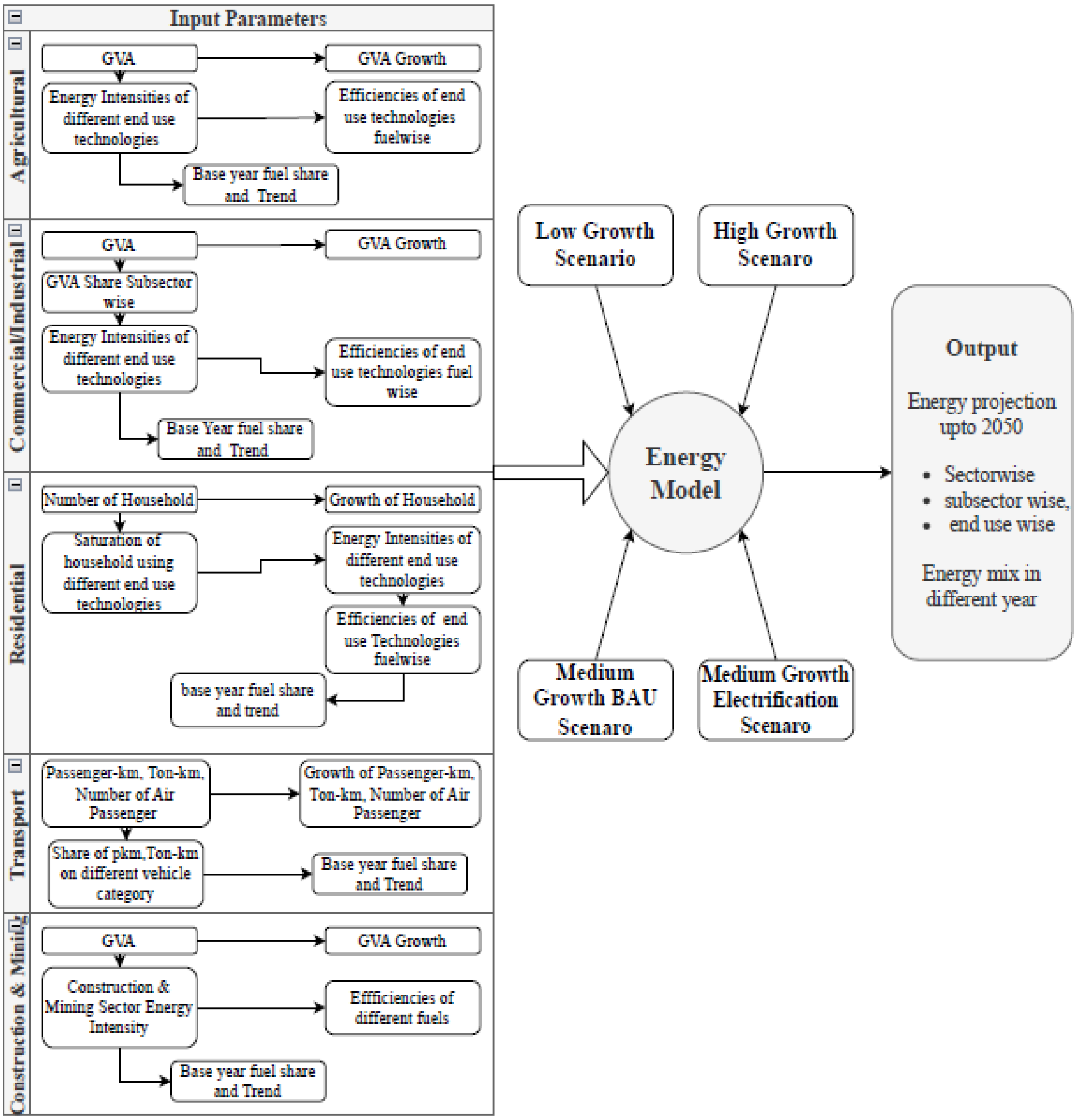

Figure 4-2: Modelling Framework

4.2 Baseline Assumptions

In the energy model energy and electricity consumption intensity by different end-use technologies for different sectors, sectoral GVA for industrial, commercial, agricultural, and construction, mining sectors, number of households for the residential sector, passenger-km, ton-km, and number of air passengers for the transport sector are given as input for the base year 2021, also fuel share in the base year is used from the provincial energy reports published by WECS In the model for the base year (2021), the following input data is collected from different organizations

Table 4-1: Sources of base of year data

Organization/GoN Body	Information used in Base Year
Nepal Electricity Authority (NEA)	Electricity baseline data
	Growth trend of electricity
	Share of electricity in different sectors
Water and Energy Commission Secretariat (WECS)	Energy consumption in the base year
	Historical energy consumption pattern
	Energy share by different sectors, subsectors, and end use
Department of Transport Management (DoTM)	Data regarding number of vehicles: Information about the total number of vehicles categorized by type (e.g., cars, motorcycles, buses, trucks, etc.)
Civil Aviation Authority of Nepal (CAAN)	Data on air passengers and trend over past years
Central Bureau of Statistics (CBS)	GVA Growth trend: Historical data on the growth rate of Gross Value Added in each sector
	Number of households: Data on the total number of households in Nepal on the base year 2021.
	Population: Information on the total population of Nepal in the base year.
	Sectoral GVA (Gross Value Added) for industrial, commercial, agricultural, and construction, mining sectors.
Alternative Energy Promotion Center (AEPC)	Data regarding the number of households using biogas for cooking

All these input data sources were used for building a comprehensive energy model, which was used in understanding energy consumption patterns, forecasting future energy demands, and formulating energy policy and planning.

4.3 Scenario Assumptions

In the energy model, four distinct energy and electricity forecasting scenarios have been established: Low Growth Scenario, BAU Scenario, High Growth Scenario, and Electrification Scenario. These scenarios are shaped by three main macroeconomic factors: population growth, GDP/GVA growth, and fuel share trend. The scenarios incorporate different GDP growth rates (average growth of 4.817%, medium: average growth of 7.727%, and high: average growth of 10.487%) and population in different year (shown in annex) to determine energy demand variations. The variation of GDP in energy model is shown in table 4-2:

Table 4-2: GDP Growth Consideration

Year	Low Growth (%)	Medium Growth (%)	High Growth (%)
2021	2.7	3.1	3.6
2022	3.5	6	7.5
2023	4	6.5	8.5
2024	4.5	7	9.5
2025-2029	5	7.5	10
2030-2034	5	8	12
2035-2039	5	8.5	11.5
2040-2044	5	8.3	11
2045-2049	5	8	10.5

The growth in various sectors is influenced by different driving factors, with GDP and population playing pivotal roles in this process. These driving factors have been illustrated as follows:

Table 4-3: Driving Factors for Sector wise Growth

<table>
<tr><th>Sector</th><th>Subsector</th><th>Driving Factors</th></tr>
<tr><td>Agricultural</td><td rowspan="5">All Subsector</td><td rowspan="4">GDP</td></tr>
<tr><td>Commercial</td></tr>
<tr><td>Industrial</td></tr>
<tr><td>Construction & Mining</td></tr>
<tr><td>Residential</td><td>GDP & Population</td></tr>
<tr><td rowspan="4">Transport</td><td>Public</td><td>GDP & Population</td></tr>
<tr><td>Private</td><td>GDP & Population</td></tr>
<tr><td>Freight</td><td rowspan="2">GDP</td></tr>
<tr><td>Air</td></tr>
</table>

Based on past trends in the Gross Value Added (GVA) share of different sectors, future trends are forecasted. These projections are used to obtain the projected GVA of various sectors, including agricultural, industrial, commercial, and construction/mining sectors.

For the transportation sector, projections for passenger-km, ton-km, and air passenger numbers are calculated by considering transportation sector projected GVA and population data, while taking appropriate elasticity factors into account. Similarly, in the residential sector, household growth is calculated using population and national GVA data, incorporating suitable elasticity factors (The elasticity factors considered are mentioned in annex). The fuel trend remains consistent across most scenarios, except for the electrification ccenario, which considers specific factors leading to different fuel growth. The fuel trend projections are based on data from the synopsis report and NEA Annual report.

The electrification scenario takes into account various sources of information, including the 15th plan, white paper, Nationally Determined Contribution (NDC), and Sustainable Development Goal (SDG) documents, which have been formulated by the government. These documents provide insights and guidelines for electricity forecasting, guiding the assumptions made regarding electricity penetration in the electrification scenario.

Table 4-4: Electricity Penetration Assumptions in Electrification Scenario

Sector	Subsector	End Use	Consideration	Target Year
Agricultural	All Subsector	Water Pumping	60% Electric, 40% Solar PV	2050
		Threshing	100% Electric	
		Tilling	100% Electric	
Commercial	All Subsector	All End Use	100% Electric	2050
Industrial	All Subsector	All End Use	100% Electric	
Residential	All Subsector	Cooking	25% Electric	2030
			100% Electric	2050
		Other End Uses	100% Electric	2030
		Electricity Access/ Electrical appliances	99% Electric	
			100% Electric	2050
Transport	Public Vehicle	All Vehicles	25% Electric	2025
			50% Electric	2030
			100% Electric	2050
		Train	2 Electric Train	After 2030
	Private Vehicles	All Vehicles	30% Electric	2025
			65% Electric	2030
			100% Electric	2050
	Freight	All vehicles	50% Electric	
		Train	1 Electric Train	After 2030
Construction & Mining	All Subsector	All End Use	25% Electric	2050

4.4 Energy Forecasting

In 2021, In 2021, Nepal's energy consumption totaled 625.6 PJ. Looking ahead to 2045, different growth scenarios offer varying projections for energy consumption: low growth predicts 950.9 PJ, business-as-usual (BAU) forecasts 1603.8 PJ, electrification (Renewable Energy) estimates 940.5 PJ, and high growth anticipates 2881.6 PJ. These projections are influenced by their respective Compound Annual Growth Rates (CAGR) of 1.45%, 3.30%, 1.42%, and 5.41%. It's worth noting that Nepal's total energy consumption has consistently shown growth over the years. From 1990 to 2021, it increased from 242.6 PJ, with a CAGR of 3.103%, which aligns closely with the BAU scenario's CAGR. This indicates a persistent trend of energy demand growth. Interestingly, the medium growth (BAU) and electrification scenarios, despite assuming the same population and GDP growth, display significant differences. The electrification scenario projects a substantial reduction in total energy demand by 2045, estimated to be around 1.7 times lower compared to BAU. This highlights the transformative impact of adopting electric technology, which proves to be more efficient and less energy-intensive than conventional approaches. The electrification scenario's focus on renewable energy sources presents a promising avenue for effectively curbing energy consumption and promoting sustainable development. Energy demand projection of different sectors under different scenario is presented in annex.

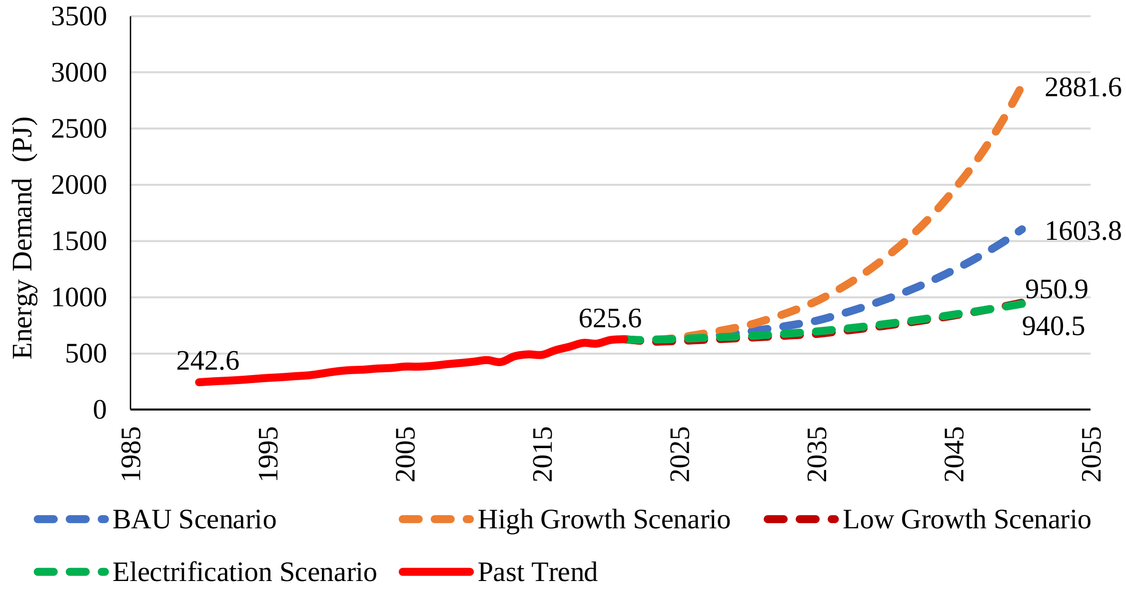

Figure 4-3: Energy Demand Projection

In the base year, electricity accounted for 4.2% of the total energy demand. Under the business-as-usual fuel trend, it is projected to reach about 30% by the year 2050. However, in the electrification scenario, the share of electricity is expected to significantly increase, reaching about 80.7% of the total energy demand by 2050. Similarly, the table presents the share of electricity in the total energy consumption of different sectors in the base year, as well as the projected growth of the share of electricity in the total energy demand of each sector for the future. For different growth scenario in business-as-usual case fuel trend is assumed same but projected fuel share of electricity is varying by few percentages due to different growth non electric fuels.

Table 4-5: Share of Electricity in Energy Demand

(In %)

Scenario	Base Year	BAU (All Growth)			Electrification (Medium Growth)		
Energy Demand	2021	2030	2040	2050	2030	2040	2050
Total	4.2	12.8 to 13.8	20.2 to 23.7	25.7 to 30.2	15.5	39.0	80.7
Agricultural	7.4	14.0	16.7	20.7	17.9	36.0	68.4
Commercial	8.7	22.3	25.5	28.6	20.7	42.2	84.2
Industrial	8.8	26.7	41.5	50.8	26.5	54.9	100.0
Residential	3.0	9.2	14.8	19.3	9.7	28.6	98.8
Transport	0.0	0.0	0.1	0.1	14.8	23.4	30.5
Construction & Mining	0.1	0.8	1.6	2.4	2.8	6.2	9.9

4.5 Electricity Forecasting

Over the years, Nepal's electricity consumption has experienced remarkable growth, soaring from 700 GWh in 1990 to an impressive 7313 GWh in 2021, marking an increase of over 10 times with a remarkable Compound Annual Growth Rate (CAGR) of 7.86%. Looking ahead to 2045, the projected electricity demand for various scenarios indicates substantial growth: 64531.4 GWh for low growth, 126217.6 GWh for medium growth (BAU), 210772. GWh for electrification, and 241926.8 GWh for high growth. These scenarios exhibit higher CAGRs compared to the past trend, highlighting the availability of new options and advancements in electric technology. The increasing adoption of electric technology in recent years has contributed to the rapid surge in electricity demand within the forecasting models. By 2050, implementing partial or full electrification of various end uses would result in an additional electricity demand of 84555 GWh, approximately 67% higher than the business-as-usual (BAU) scenario. This underscores the transformative impact of electrification and the significant potential for enhancing energy consumption patterns and promoting sustainable energy practices in Nepal's energy landscape. Policymakers can leverage these projections to guide energy planning and foster the widespread adoption of electric technology, promoting a greener and more resilient energy future for the nation. Electricity demand projection of different sectors under different scenario is presented in annex.

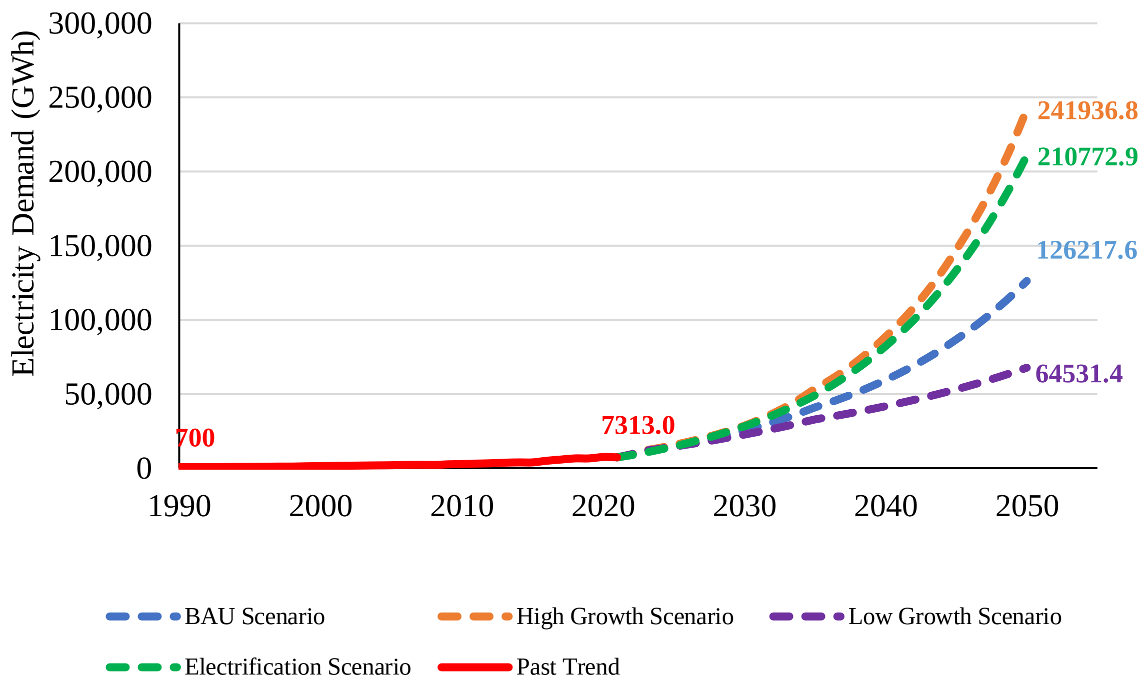

Figure 4-4: Electricity Demand Projection

4.5.1 Electricity Generation Forecast

For the electrification scenario's electricity demand in 2050, the generation capacity should align with the high growth trend. This means that a rapid and substantial increase in electricity generation will be necessary to meet the higher demand resulting from widespread electrification.

Table 4-6: Electricity Generation and Demand Forecast

Year	Generation Forecast (GWh)			Demand Forecast (GWh)			
	High	Medium	Low	BAU	High	Low	Electrification
2021	12271	11526	9763	7313			
2025	48717	30842	17935	15118	15670	14501	14616
2030	94172	54934	28129	25493	28654	22667	28201
2035	139516	78967	38297	40994	53459	32868	49122
2040	184748	102941	48440	59498	88603	41787	82225
2045	229870	126856	58558	86758	147007	53153	133265
2050	274881	150713	68652	126218	241937	67756	210773

However, to meet the electricity demand in 2030 and 2040, a lower growth trend of electricity generation, specifically low growth for 2030 and medium growth for 2040, would be sufficient. These earlier timeframes may not require the same level of rapid expansion in generation capacity as projected for the electrification scenario in 2050.

CHAPTER FIVE: SECTORAL ELECTRICITY DEMAND

In the process of electricity forecasting, various scenarios were considered, including the electrification scenario. This scenario involved assuming how electricity would be adopted and integrated into different sectors' technologies. The results of the electrification scenario were used as a critical foundation for conducting detailed sector-wise analysis. By examining each sector's response to electricity penetration, potential implications on overall elecricity demand were analyzed. In the electrification scenario, the approach was to electrify different end-use technologies in sectors, either partially or fully. However, it was recognized that specific key technologies within each sector contributed significantly to overall energy consumption and electricity demand. For example, in the residential sector, cooking activities accounted for a substantial amount of energy usage. When these cooking technologies were switched to electric options, a significant portion of residential electricity demand was attributed to cooking alone. To stimulate higher electricity demand in different economic sectors, priority end use was also analyzed from different perspective.

5.1 Agricultural Sector

5.1.1 Baseline Information

Over the past two decades, the agricultural industry has undergone notable changes in its electricity consumption, as presented in Table 5-1: Overview Agricultural Electricity Demand. Specifically, the Compound Annual Growth Rate (CAGR) of the agricultural sector's Gross Value Added (GVA) has shown a growth of 3.11%. In contrast, electricity consumption and electrical intensity has experienced a more substantial 10.28% and 6.95% during the same period.

Table 5-1: Overview Agricultural Electricity Demand

Description	2001	2021	CAGR
Agricultural GVA (Million NRs,2010-2011)	358284	661655	3.11%
Agricultural Electricity Demand (GWh)	28.6	202.7	10.28%
Agricultural Electricity Share (Of Total Demand)	2.23%	2.77%	1.08%
Agricultural Electricity Intensity (kWh/Rs)	0.08	0.31	6.95%
Irrigated Area (Hectare)	18815*	187521	21.12%

** Value of 2009*

5.1.2 Electricity Demand

The electricity demand in agricultural sector is expected to rise to a value of 4559 GWh by 2050 In electrification which with a strong CAGR of 11.33% is about two times electricity demand in medium growth business as usual scenario. Similarly, the electrical intensity is expected to rise to value of 1.31 kWh/Rs in electrification scenario and 0.69 GWh in Bau scenario.

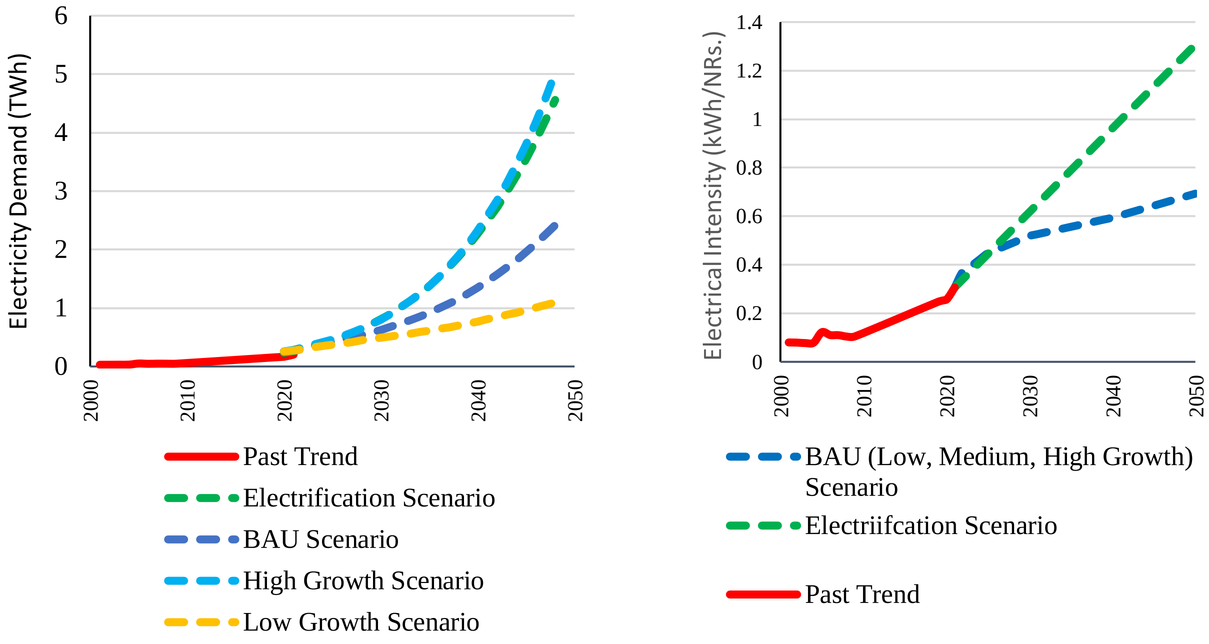

Figure 5-1: Electricity Demand in Agricultural Sector

The total electricity demand and growth of electricity demand and electrical intensity in different scenario are shown in Table 5-2, which show the robust growth in electricity demand in electrification and high econmic growth scenarios with cagr more tha 11% on each.

Table 5-2: Electricity Demand Projection in Agricultural Sector

Description	Low Growth	Medium Growth (BAU)	Medium Growth (Electrification)	High Growth
Agriculture Electricity Demand, 2021 (GWh)	202.7			
Agriculture Electricity Demand, 2030 (GWh)	488.6	625.8	805.5	803.5
Agriculture Electricity Demand, 2040 (GWh)	701.8	1154.3	1870.1	1891.3
Agriculture Electricity Demand, 2050 (GWh)	1093.4	2416.8	4558.8	5021.5
CAGR of Electricity Demand, 2021-50	5.98%	8.92%	11.33%	11.70%
CAGR of Electrical Intensity, 2021-50	2.85%	2.85%	5.13%	2.85%

Under different economic growth scenarios in the Business as Usual (BAU) fuel trend, the electricity consumption in the agricultural sector will continue to be proportional to the value of agricultural output, resulting in the same electrical intensity across all growth cases. However, in the Electrification scenario, a higher intensity is observed due to strategic planning and adjustments aimed at maximizing the utilization of electric equipment and cutting-edge technologies for agricultural activities. This deliberate approach to electrification drives the increased demand for electricity in the agricultural sector.

5.1.3 Priority End Use

In the base year, the primary electricity consumption in the agricultural sector is mainly due to the usage of pumps for irrigation purposes. Table 6-1 indicates a Compound Annual Growth Rate (CAGR) of 21.12% in irrigated land from last 13 years, showcasing a high increase in irrigation activities. Additionally, the NEA report for 2021-2022 highlights a substantial rise in electricity sales in water supply and irrigation, growing at a CAGR of 10.28% over the past decade. Currently, the electricity demand for agricultural water pumping, including both electric and solar pumping, stands at 202.52 GWh.

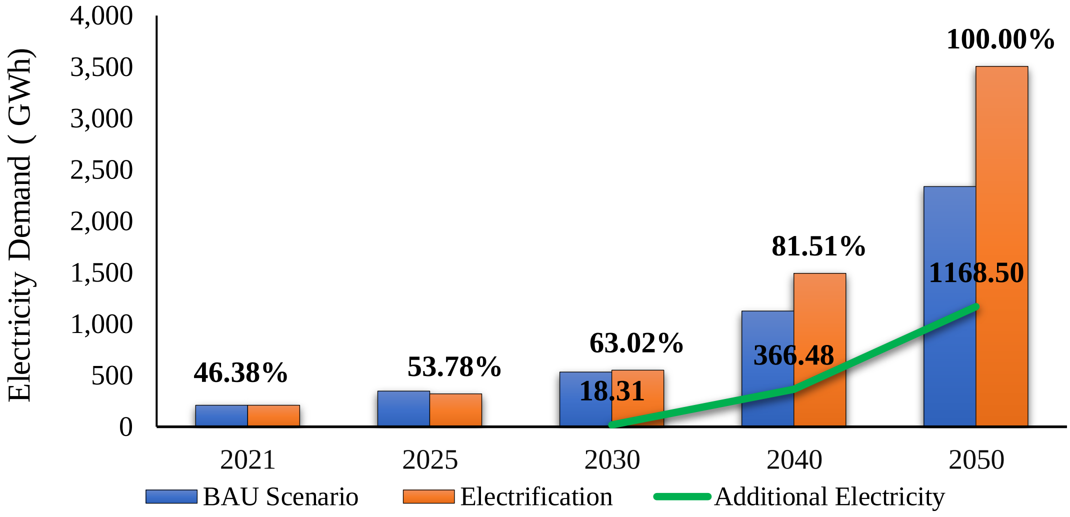

Figure 5-2: Electricity Demand by Agricultural Water Pumping

According to the medium growth scenario, this demand is projected to rise to 2337.1 GWh by the year 2050. In the Electrification scenario, the demand is expected to reach 3505.6 GWh by the same year, with respective Compound Annual Growth Rates (CAGR) of 8.67% and 10.2%. Notably, in the years 2030, 2040, and 2050, the Electrification scenario is predicted to generate additional electricity demand compared to the Business-as-Usual scenario in the medium growth rate scenario, with increments of 18.31 GWh, 366.48 GWh, and 1168.50 GWh, respectively. The Electrification scenario for the agricultural sector sets ambitious targets, aiming to achieve 53.78% electric water pumping by 2025, 63.02% by 2030, and ultimately 100% by 2050. The scenario focuses on maximizing the adoption of electric water pumping technology, contributing to increased electricity demand for agricultural purposes over time

5.1.4 Financial Analysis

When after conducting a comprehensive 10-year financial analysis, considering investment, repair, maintenance costs, and fuel expenses for both electric and diesel/petrol pumps, it is estimated that the electric water pump will recoup its investment in approximately 6 years without any subsidies. However, with subsidies of 20% and 50%, the payback period decreases to 5 years and 3.45 years, respectively, making it a more attractive option. Moreover, when factoring in the health and carbon emission benefits of using an electric water pump over a diesel or petrol pump, the payback period experiences a slight reduction in economic analysis compared to the results of the financial analysis. Furthermore, it's worth noting that the internal rate of return surpasses the discount rate of 12%, indicating that the investment is not only favourable but also profitable.

Table 5-3: Financial and Economic Analysis of Agricultural Water Pumping

Financial Parameters	Financial Analysis			Economic Analysis		
Subsidies	0%	20%	50%	0%	20%	50%
Net Present Value (NRs)	22,701	28,701	37,701	25,959	31,959	40,959
Internal Rate of Return	14%	19%	32%	16%	21%	35%
Payback Period (Years)	5.94	5.03	3.45	6.60	4.72	3.21

5.2 Commercial Sector

5.2.1 Baseline Information

The service sector is experiencing significant growth in electricity demand with a strong CAGR of about 13%, despite this high demand for electricity, the share of electricity consumption within the service sector has doubled in last twenty years. The reason for this high growth in share is the due to substantial increase in electricity consumption This growth in commercial GVA acts as a driving force for the expansion and development of the electricity demand in commercial sector.

Table 5-4: Overview Commercial Electricity Demand

Description	2001	2021	CAGR
Commercial GVA (Million NRs) (2010-11)	449,450	1,163,214	4.87%
Commercial Electricity Demand (GWh)	94.2	1055.5	12.84%
Commercial Electricity Share	7.35%	14.41%	3.42%
Commercial Electricity Intensity (kWh/Rs)	0.21	0.91	7.60%

5.2.2 Electricity Demand

In the base year, the commercial sector's electricity consumption was 1055 GWh. However, in the electrification scenario, it is expected to reach 43,694 GWh, which is 85% higher than the business-as-usual scenario with medium GVA (Gross Value Added) growth assumptions.

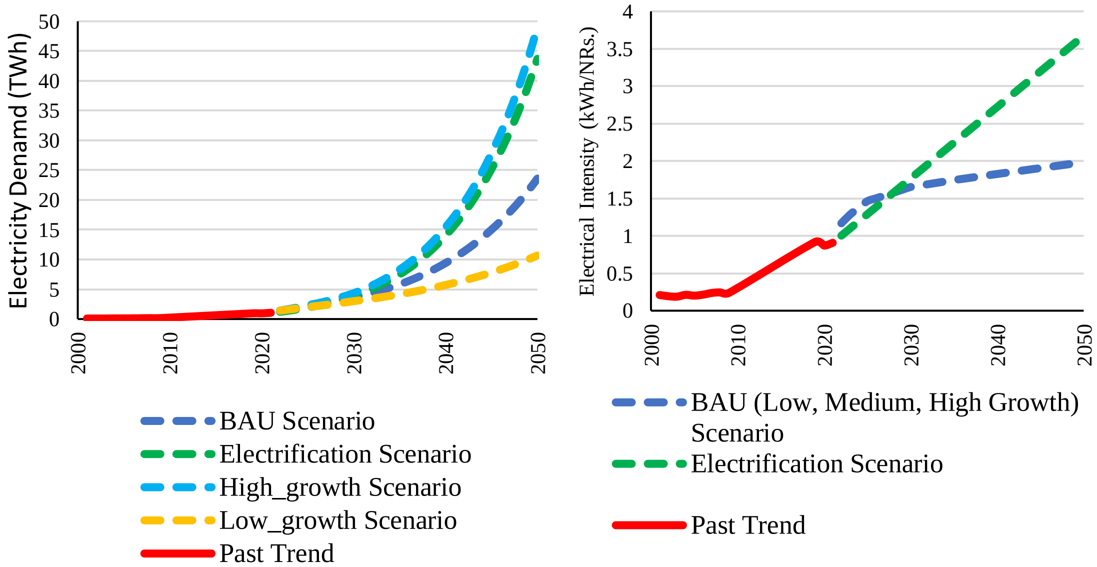

Figure 5-3: Electricity Demand in Commercial Sector

By the year 2050, electricity intensity is expected to reach an of 3.7 kWh/Rs in electrification scenario. Forecast expected a significant rise in electricity demand, particularly in the electrification and high economic growth scenarios.

Table 5-5: Electricity Demand Projection in Commercial Sector

Description	Low Growth	BAU	Electrification	High Growth
Commercial Electricity Demand, 2021 (GWh)	1055.4			
Commercial Electricity Demand, 2030 (GWh)	2999.4	3637.2	3888.1	4335.2
Commercial Electricity Demand, 2040 (GWh)	5715.4	9400.6	14004.3	15402.5
Commercial Electricity Demand, 2050 (GWh)	10670.6	23586.6	43693.7	49007.5
CAGR of Electricity Demand, 2021-50	8.30%	11.31%	13.70%	14.15%
CAGR of Electrical Intensity, 2021-50	2.73%	2.73%	4.94%	2.73%

However, it's worth noting that even the low growth and medium growth business-as-usual scenarios exhibit substantial growth in electricity demand within the commercial sector.

5.2.3 Priority End Use

In 2021, the electricity consumption for electric cooking in the commercial sector was 24 GWh. By 2050, under different scenarios, the projected electricity consumption is expected to reach 11,516 GWh in the Medium growth business-as-usual scenario, 23,928 GWh in the High growth scenario, 5,210 GWh in the Low growth scenario, and 31,568 GWh in the Electrification scenario. These scenarios have corresponding compound annual growth rates (CAGR) of 23.71%, 26.87%, 20.38%, and 28.09% respectively. To achieve a target of 100% electrification of cooking in the commercial sector by 2050, additional electricity demand will be created as follows: 332 GWh by 2030, 4,700 GWh by 2040, and 20,052 GWh by 2050.

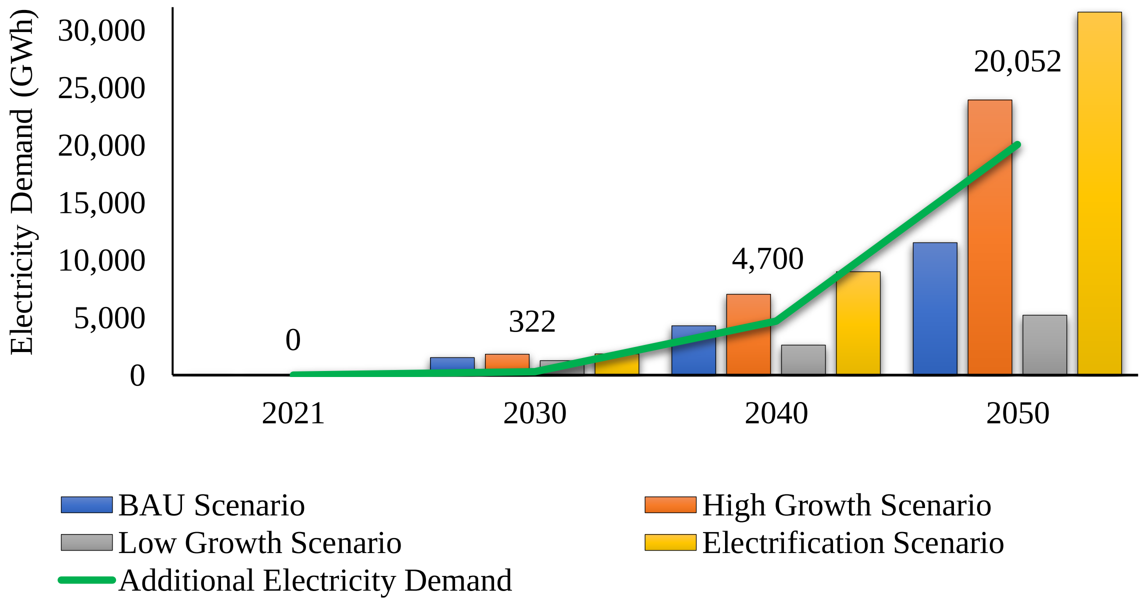

Figure 5-4: Electricity Demand Projection in Commercial Cooking

5.2.4 Financial Analysis

After conducting a thorough financial analysis spanning 7 years, taking into account investment costs, utensil and wiring expenses, and repair and maintenance costs (which amount to 5% of the initial investment), as well as fuel costs for both electric and traditional LPG technologies, it is evident that the investment in commercial electric cooking technology is covered within life span of technology. The initial investment is projected to be recuperated in around 2 years without any subsidies. However, with subsidies of 20% and 50%, the payback period reduces significantly to 1.76 years and 1.29 years, respectively. Furthermore, when factoring in the health and carbon emission benefits associated with using electric cooking appliances, the payback period is further enhanced in the economic analysis., the investment remains favourable, as the internal rate of return still exceeds the discount rate of 50%, underscoring the profitability of this venture.

Table 5-6: Financial and Economic Analysis of Commercial Electric Cooking

Financial parameters	Financial Analysis			Economic Analysis		
Subsidies	0%	20%	50%	0%	20%	50%
Net Present Value (NRs)	184,881	194,881	209,881	186,480	196,480	211,480
Internal Rate of Return	52%	62%	85%	53%	62%	86%
Payback Period (Years)	2.06	1.76	1.29	2.05	1.75	1.28

5.3 Industrial Sector

5.3.1 Baseline Information

Table 5-7 shows various parameters related to electricity demand in the industrial sector for the base year and its growth over the past 20 years. The table highlights a significant increase in industrial electricity demand and electricity consumption per unit value added by the industrial sector. Despite this high growth in demand, the share of total electricity consumption by the industrial sector has slightly decreased due to the increased electricity demand in the residential, agricultural, commercial, and other sectors over the last five years.

Table 5-7: Overview of Industrial Electricity Demand

Description	2001	2021	CAGR
Industrial GVA (Million NRs) (2010-11)	76754	131257	2.72%
Industrial Electricity Demand (GWh)	520.6	2823.2	8.82%
Industrial Electricity Share	40.64%	38.54%	-0.27%
Industrial Electricity Intensity (kWh/Rs)	6.8	21.5	5.94%

5.3.2 Electricity Demand

Different scenarios have been considered to project the electricity demand and electrical intensity for the industrial sector up to the year 2050. In the base year, the industrial sector's electricity consumption demand was 2823 GWh. However, the Electrification scenario anticipates a substantial increase, with the demand expected to reach around 116925 GWh by 2050. This indicates a 45% higher electricity demand compared to the Business-as-Usual scenario, assuming normal growth conditions. Similarly, in the Electrification scenario, the projected electrical intensity is set to reach 130.9 kWh/Rs by 2050, marking a 45% higher compared to the Business-as-Usual scenario. This growth in electrical intensity is a result of strategic efforts and the widespread adoption of electric technologies and equipment within the industrial sector.

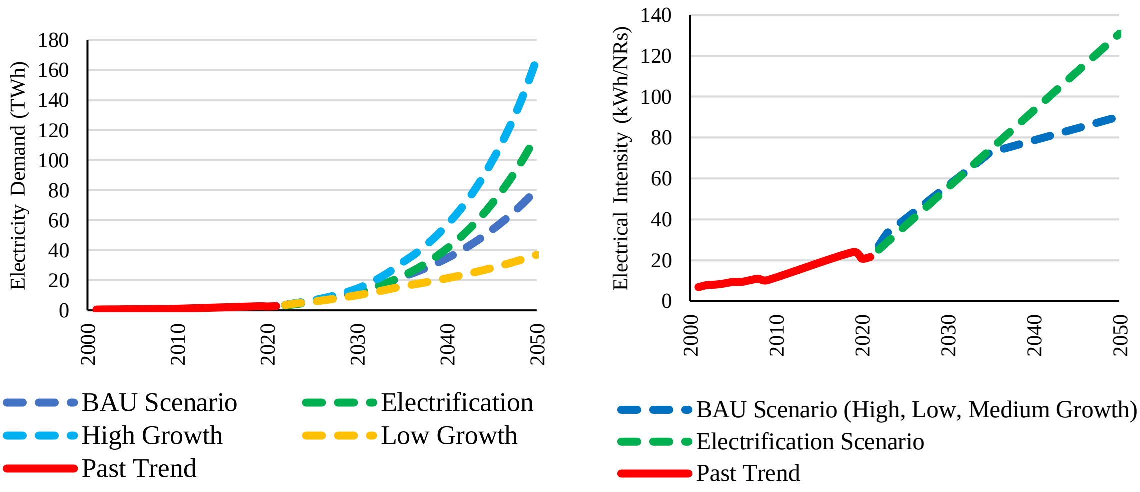

Figure 5-5: Electricity Demand in Industrial sector

The total electricity demand and growth of electricity demand and electrical intensity in different scenario are shown in Table 5-8, which show the robust growth in electricity demand in electrification and high econmic growth scenarios also growth is high in other scenarios too.

Table 5-8: Electricity Demand Projection in Industrial Sector

Description	Low Growth	Medium Growth (BAU)	Medium Growth (Electrification)	High Growth
Industrial Electricity Demand, 2021 (GWh)	2823.2			
Industrial Electricity Demand, 2030 (GWh)	10045.0	12099.3	11892.7	14421.0
Industrial Electricity Demand, 2040 (GWh)	21305.6	34688.8	41099.8	56835.7
Industrial Electricity Demand, 2050 (GWh)	36984.7	80657.6	116925.1	167587.9
CAGR of Electricity Demand, 2021-2050	9.28%	12.25%	13.70%	15.12%
CAGR of Electrical Intensity, 2021-2050	5.07%	5.07%	6.42%	5.07%

5.3.3 Priority End Use

5.3.3.1 Motive Power

Industrial motive power, which includes motors, pumps, and compressors, is currently the most electricity-consuming technology in industries, accounting for around 1558 GWh, which is more than double the electricity consumed by boilers and process heat combined. When comparing the electricity projections for the Business-as-Usual (BAU) scenario and the Electrification scenario for industrial motive power, it becomes evident that both scenarios show a nearly equal total electricity consumption in the years 2040 and 2050. This

Table 5-9: Electricity Demand Projection for Industrial Motor

(GWh)

Scenario	2021	2030	2040	2050
BAU Scenario	1,558.5	4,310.2	10,649.8	23,013.0
High Growth Scenario		5,137.3	17,449.1	47,815.8
Low Growth Scenario		3,554.4	6,474.9	10,411.0
Electrification Scenario		3,545.0	9,552.9	23,930.

The Electrification scenario assumes a further increase in electrification efforts. However, the projections suggest that this additional push towards electrification may not lead to a substantial increase in electricity demand for industrial motive power. The reason being that electricity is already making significant inroads into industrial operations, as indicated by the current fuel consumption trends.

5.3.3.2 Boiler

When comparing the electricity demand forecast for industrial boilers between the Business-as-Usual (BAU) scenario and the Electrification scenario, it is projected that by the year 2040, there will be an additional electricity demand of approximately 310 GWh. In the more extended term, by the year 2050, the Electrification scenario anticipates an even higher additional electricity demand of around 500 GWh for industrial boilers. These projections indicate that the Electrification scenario would lead to a substantial increase in electricity consumption compared to the BAU scenario, primarily driven by the electrification trend assumption of 100% electric boiler by 2050 in the industrial sector.

Table 5-10: Electricity Demand Projection for Industrial Boiler

(in GWh)

Scenario	2021	2030	2040	2050
BAU Scenario	61.4	2,583.8	8,330.1	19,415.5
High Growth Scenario		3,079.6	13,648.4	40,341.0
Low Growth Scenario		2,130.7	5,064.6	8,783.6
Electrification Scenario		2,045.4	8,642.6	26,481.3

5.3.3.3 Furnace

The industrial furnace stands out as the most electricity-consuming end-use for industries, currently accounting for approximately 662 GWh of electricity consumption. However, when forecasting the electricity demand for the industrial furnace under the Electrification and Business-as-Usual (BAU) scenarios, with medium Gross Value Added (GVA) growth, significant differences emerge.

Table 5-11: Electricity Demand Projection for Industrial Furnace

(in GWh)

Scenario	2021	2030	2040	2050
BAU Scenario	661.8	3,753.7	11,43.0	26,952.5
High growth Scenario		4,474.0	18,700.0	56,001.2
Low growth Scenario		3,095.5	6,938.9	12,193.4
Electrification Scenario		4,787.2	18,21.0	54,138.3

In the Electrification scenario, there is a substantial increase in electricity demand. By the year 2040, the additional electricity demand for electrification, compared to the BAU scenario, is projected to be about 7,000 GWh. The difference becomes even more pronounced in the year 2050, with an additional electricity demand of approximately 28,000 GWh for the industrial furnace alone in the Electrification scenario. These projections indicate that the adoption of electrification, especially in the industrial furnace sector, would result in a significant surge in electricity consumption compared to the BAU scenario, highlighting the potential impact of embracing electrification in industrial processes. In the context of the industrial sector, policy-makers should prioritize the adoption of electric furnaces while developing future strategies. Due to high electricity demand creation possibilities of furnaces.

5.3.4 Financial Analysis

5.3.4.1 Industrial Boiler

The financial analysis of industrial electric boilers compared to traditional boilers shows that the payback period without subsidies is approximately 8.66 years, considering the boiler's lifespan to be 15 years. However, with subsidies of 20% and 50%, the payback period decreases to 7.62 and 5.80 years, respectively, making the investment more attractive. Moreover, when different social and environment benefits provided by electric boilers are taken into account, the payback period is further improved, making the investment even more favourable. In terms of the internal rate of return (IRR), without subsidies, it is found to be less than the discount rate of 12%. However, when subsidies or social benefits are considered, the IRR exceeds the discount rate of 12%.

Table 5-12: Financial and Economic Analysis of Electric Boiler

Financial Parameters	Financial Analysis			Economic Analysis		
Subsidies	0%	20%	50%	0%	20%	50%
Net Present Value (NRs)	507,974	607,974	757,974	537,991	683,016	760,975
Internal Rate of Return	11%	14%	21%	12%	16%	21%
Payback Period (Years)	8.66	7.62	5.80	8.44	7.10	5.78

5.3.4.2 Industrial Furnace

The industrial electric furnace has a payback period of 8.33 years without subsidies. However, with subsidies of 20% and 50%, the payback period decreases to 6.36 years and 4.35 years, respectively. The analysis is conducted over a 15-year period. Additionally, it is important to note that the internal rate of return (IRR) exceeds the 12% discount rate for all cases involving subsidies.

Table 5-13: Financial and Economic Analysis of Electric Furnace

Financial Parameters	Financial Analysis			Economic Analysis		
Subsidies	0%	20%	50%	0%	20%	50%
Net Present Value (NRs)	1,081,567	1,281,567	1,581,567	1,156,610	1,356,610	1,584,569
Internal Rate of Return	12%	15%	23%	13%	16%	23%
Payback Period (Yrs)	8.33	6.26	4.35	8.07	6.00	5.34

5.4 Residential Sector

5.4.1 Baseline Information

The table illustrates various factors influencing the rise in electricity demand within the residential sector. Notably, there has been a significant surge in electricity consumption among households, especially as the primary source for cooking purposes. Over the past decade, the number of households relying on electricity for cooking has experienced substantial growth, surpassing the increase in households using LPG for cooking.

Table 5-14: Overview of Residential Electricity Demand

Description	2001	2021	CAGR
Number of Households (HH)	4253220	6660841	2.27%
Residential Electricity Demand (GWh)	518.4	3241.2	9.60%
Residential Electricity Share	40.46%	44.24%	0.45%
Residential Electricity Intensity (kWh/HH)	121.9	486.6	7.17%
Population (Million)	23.1514	29.1646	1.16%
National GVA, Million NRs, (2010-11)	1005659	2263570	4.14%
HH using Electric Cooking	4253*	33304	22.85%
HH using Electric Lighting	39.80%	92.20%	4.29%
HH using LPG Cooking	327498	2950753	11.62%
			**Value of 2011*

5.4.2 Electricity Demand

In the base year, the electricity consumption of the residential sector was approximately 3241 GWh. However, in the electrification scenario, this consumption is projected to increase significantly to reach around 32555 GWh by the year 2050. This represents a substantial 71% higher electricity demand compared to the business-as-usual scenario under the assumption of medium growth. Additionally, in the electrification scenario, the electrical intensity is expected to rise to 3405 kWh per household, whereas in the business-as-usual scenario, it is predicted to be 1995 kWh per household. These figures indicate a considerable difference in electricity usage patterns between the two scenarios.

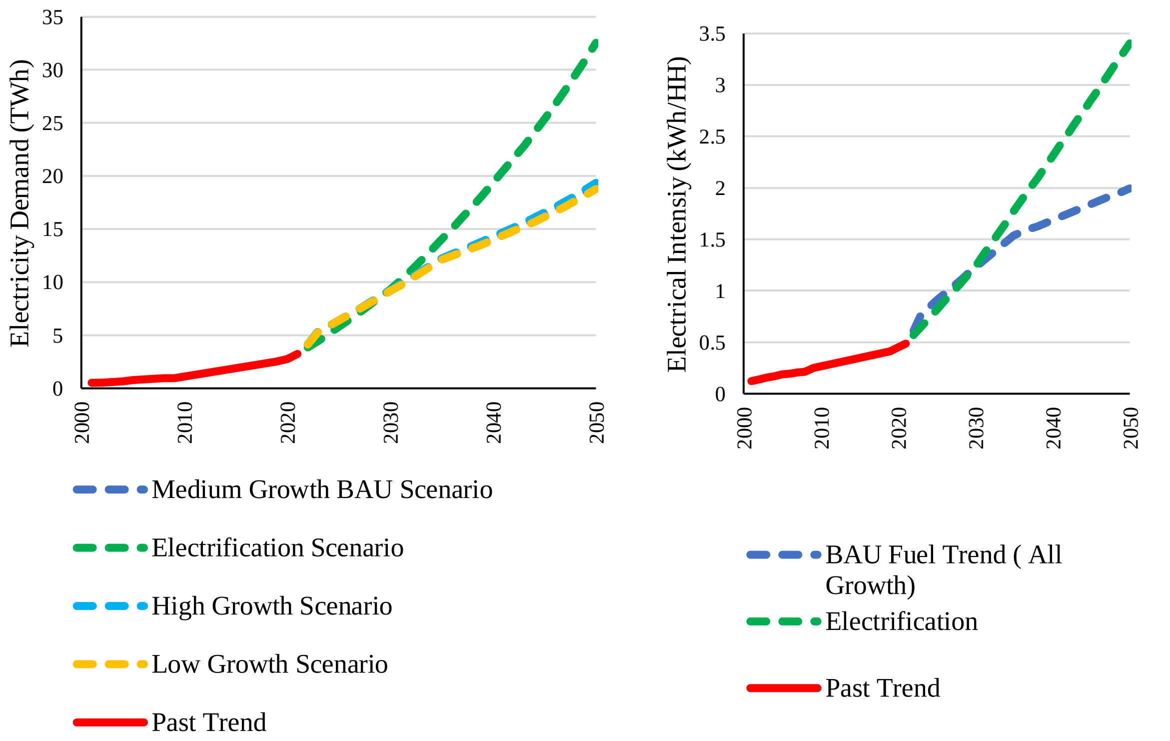

Figure 5-6: Electricity Demand in Residential Sector

The Table 5-15 presents projections for total electricity demand and electrical intensity across different growth scenarios. It is evident from the table that the electrification scenario exhibits a substantially growth rate compared to the other scenarios.

Table 5-15: Electricity Demand Projection in Residential sector

Description	Low Growth	Medium Growth (BAU)	Medium Growth (Electrification)	High Growth
Residential Electricity Demand, 2021 (GWh)	3241.2			
Residential Electricity Demand, 2030 (GWh)	9151.4	9186.8	9253.2	9219.1
Residential Electricity Demand, 2040 (GWh)	13976.3	14116.1	19327.9	14256.2

Description	Low Growth	Medium Growth (BAU)	Medium Growth (Electrification)	High Growth
Residential Electricity Demand, 2050 (GWh)	18779.8	19080.1	32554.8	19361.2
CAGR of Electricity Demand, 2021-2050	6.25%	6.30%	8.28%	6.36%
CAGR of Electrical Intensity, 2021-2050	5.0%	5.0%	6.9%	5.0%

5.4.3 Priority End Use

5.4.3.1 Electric Cooking

In the residential sector, cooking stands out as the most energy-consuming end-use in terms of electricity, while lighting, space cooling, and electrical appliances also contribute significantly to electricity consumption. However, it is noteworthy that many of these end-uses are already predominantly electric, which means there is little additional electricity demand expected from them due to the saturated fuel trend. In contrast, cooking presents a unique opportunity for electrification, as a significant portion is still reliant on LPG and wood as cooking fuels. The potential to convert LPG and wood cooking to electric cooking opens up a wide range of possibilities, leading to increased electricity demand in the residential sector. In the scenario with 200% electric cooking by the year 2050, there will be a considerable surge in electricity demand. Projections indicate that by 2030, an additional electricity demand of 0.144 TWh will be created. This demand is expected to grow to 4.322 TWh by 2040 and further increase to 11.018 TWh by 2045.

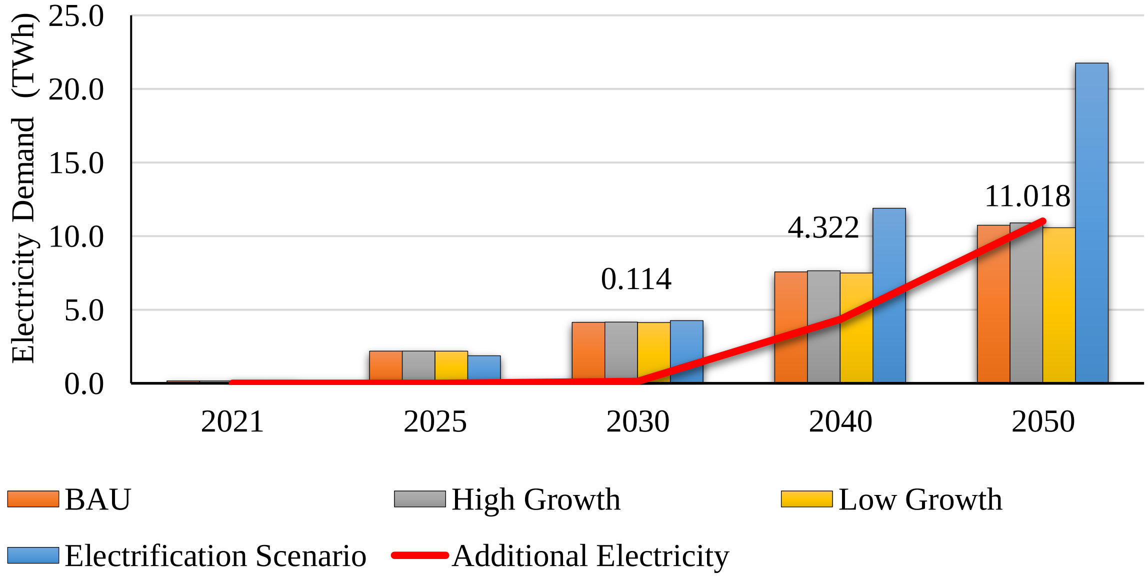

Figure 5-7: Electricity Demand Projection in Residential Cooking

Comparing the Compound Annual Growth Rate (CAGR) of the Business-as-Usual trend and the Electrification scenario, we see that the CAGR for the BAU trend is approximately 15.6%. However, with the application of the Electrification scenario, the CAGR rises to 18.45%. This significant increase in the CAGR underscores the potential impact of electrification in the residential cooking sector, and the crucial role it can play in shaping the future electricity demand. Embracing electric cooking has the potential to bring numerous benefits, including reduced greenhouse gas emissions, improved indoor air quality, and increased energy efficiency. Policy-makers should focus on promoting the adoption of electric cooking technologies. By doing so, they can seize the opportunity to meet the rising electricity demand while advancing towards a more sustainable and electrified future.

5.4.4 Financial Analysis

The financial analysis of household electric cooking is conducted over a 5-year period, considering various factors such as initial investment, utensil and wiring costs, repair and maintenance expenses, electricity costs, and fuel costs for traditional cooking technologies. Without any subsidies, the payback period for electric cooking is calculated to be 2.36 years. However, with subsidies of 20% and 50%, the payback period decreases to 2.05 years and 1.52 years, respectively. Moreover, the analysis reveals a robust internal rate of return (IRR) of more than 40%, which significantly exceeds the discount rate. This indicates a highly profitable investment opportunity for household electric cooking, making it an economically favourable choice than cooking with LPG.

Table 5-16: Financial and Economic Analysis of Residential Electrical Cooking

Financial Parameters	Financial Analysis			Economic Analysis		
Subsidies	0%	20%	50%	0%	20%	50%
Net Present Value (NRs)	23,231	26,231	30,731	24,413	27,413	31,913
Internal Rate of Return	36%	46%	67%	38%	47%	69%
Payback Period (Years)	2.36	2.05	1.52	2.30	1.99	1.47

5.5 Transport Sector

5.5.1 Baseline Information

The electricity demand in the transport sector has been experiencing a decline with a medium growth rate. This decrease can be attributed to historical factors, such as the use of trolley buses, electric cables cars, and ropeways for electricity consumption in Nepal during the year 2001. However, over the years, these methods were discontinued, leading to a reduction in electricity demand. Furthermore, despite the recent boom in electric vehicle (EV) technologies, the electricity consumption in the transport sector remains low even in the base year 2021. This is primarily due to the significant decrease in electricity intensity in this sector, which is a result of the high Gross Value Added

(GVA) growth in transport activities and a simultaneous decrease in electricity demand. Different baseline information regarding passenger-kilometers and ton-km of different vehicles are enlisted in annex.

Table 5-17: Overview of Transport Sector electricity Demand

Description	2001	2021	CAGR
Transport Sector Electricity Demand (GWh)	5.89	1.94	-5.40%
Transport Share Electricity Share	0.4600%	0.0260%	-13.38%
Population (Million)	23.15142	29.16458	1.16%

5.5.2 Electricity Demand

In 2021, the electricity consumption in the transport sector was 1.96 GWh. However, in the electrification scenario projected for 2050, this demand is expected to increase significantly to 11,557 GWh, which is more than 265 times the electricity demand in the business-as-usual scenario, assuming similar growth in passenger-km and ton-km. The forecasted electricity demand in other scenarios is comparatively much lower than that of the electrification scenario. This is mainly due to the fact that while there has been a recent boom in electric technology and high growth trends in recent years, the actual base year data for electricity demand in the transport sector was very low. Despite the high growth trend, the initial low base value results in lower forecasting figures in these alternative scenarios.

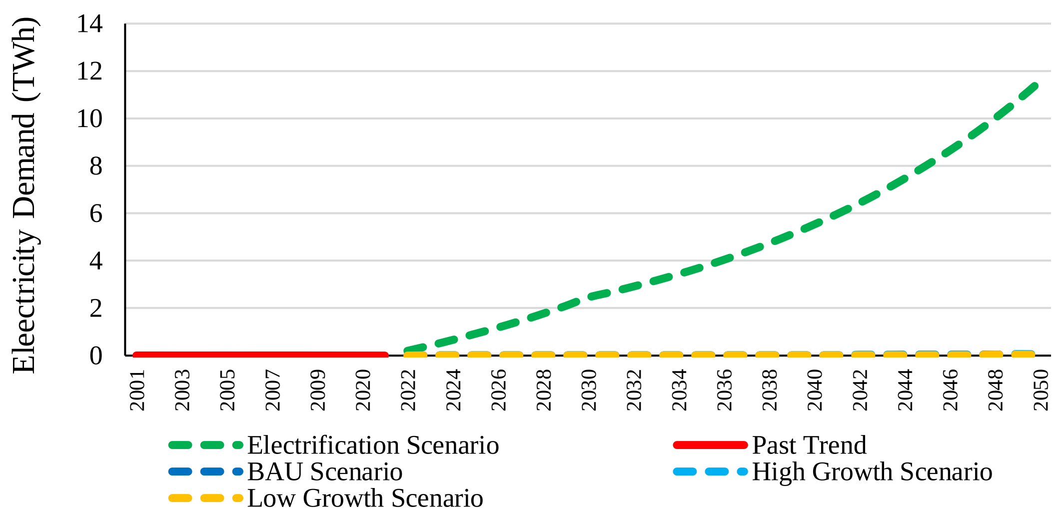

Figure 5-8: Electricity Demand in Transport Sector

Projected electricity demand in different scenario and growth rate related to this projection is presented in Table 5-18.:

Table 5-18: Electricity Demand Projection in Transport Sector

Description	Low Growth	Medium Growth (BAU)	Medium Growth (Electrification)	High Growth
Transport Sector Electricity Demand, 2021 (GWh)	1.94			
Transport Sector Electricity Demand, 2030 (GWh)	6.8	7.4	2449.6	8.0
Transport Sector Electricity Demand, 2040 (GWh)	15.7	19.2	5523.6	23.5
Transport Sector Electricity Demand, 2050 (GWh)	31.2	43.3	11556.6	58.5
CAGR of Electricity Demand, 2021-2050	4.44%	4.73%	27.92%	4.99%

5.5.3 Priority End Use

5.5.3.1 Electrical Vehicle

The transportation sector is classified into four categories during energy modelling: public transport, private transport, freight transport, and aviation transport. In the electrification scenario, it is acknowledged that electrification of aviation and freight transport is not currently feasible given the existing technological limitations and infrastructure challenges. However, there is ongoing research and study to explore potential solutions and advancements in these areas. In contrast, the focus for electrification efforts in the transportation sector remains on public and private transport, where significant electricity demand can be created through the implementation of appropriate policies. By formulating and implementing policies that promote and incentivize the adoption of electric vehicles (EVs) in the public and private transportation domains, a substantial increase in electricity demand is anticipated.

Public Transport

In the realm of public transport, envisioning a policy aiming for 100% electrification of passenger vehicles by 2050 holds substantial potential to generate additional electricity demand. This electrification strategy, covering a diverse range of vehicles such as buses, mini and microbuses, tempos, e-rickshaws, and passenger trains (with electric trains being introduced from 2030), can have a profound impact on electricity consumption patterns. Projections indicate that by 2040, the implementation of this policy would lead to an additional electricity demand of approximately 1170 GWh, and this demand is expected to further escalate to 2510 GWh by 2045. Such a shift towards electrification in public transport is essential for promoting sustainable mobility and reducing carbon emissions

Table 5-19: Electricity Demand for Public Transport

(GWh)

Scenario/Year	2021	2030	2040	2050
BAU Scenario	1.96	3.32	5.93	10.74
Electrification Scenario		501.20	1174.56	2521.09
High Growth Scenario		3.57	7.26	14.49
Low Growth Scenario		3.07	4.84	7.76

Private Transport

When formulating a policy aimed at converting all private vehicles, including jeeps, vans, motorcycles, mopeds, two-wheelers, cars, etc., to electric vehicles (EVs) by the year 2050, it is projected that this initiative will lead to a significant surge in electricity demand. By the year 2040, the implementation of this policy would result in an additional electricity demand of approximately 1596 GWh. As the transition progresses, this demand is expected to further increase to 3170 GWh by 2045 and substantially grow to 6289 GWh by 2050.

Table 5-20: Electricity Demand for Private Transport

(GWh)

Scenario/Year	2021	2030	2040	2050
BAU Scenario	0.11	4.03	13.11	32.08
Electrification Scenario		1600.93	3183.39	6221.23
High Growth Scenario		4.33	16.05	43.30
Low Growth Scenario		3.72	10.69	23.17

Freight Transport

Presently, the feasibility of converting or transitioning freight transport to electric vehicles remains limited, with the exception of tractors where electrification is more feasible. However, for the purpose of analysis, let's assume that 25% of freight transport vehicles, including trucks, cargo vans, pickups, and mini-trucks, will be electric by the year 2050. Under this assumption, the implementation of such a policy would lead to a significant increase in electricity demand. By the year 2040, the additional electricity demand is estimated to be approximately 1165 GWh. As the transition progresses, this demand is expected to grow to 281 GWh by 2045. It is important to acknowledge that converting a portion of the freight transport sector to electric vehicles represents a step towards reducing greenhouse gas emissions and promoting cleaner transportation options. While the complete electrification of freight transport may still face challenges, the gradual adoption of electric vehicles in this sector can contribute to a more sustainable and eco-friendly future

Table 5-21: Electricity Demand for Freight Transport

(GWh)

Scenario/Year	2021	2030	2040	2050
BAU Scenario	0.00	0.06	0.18	0.43
Electrification Scenario		347.43	1165.71	2814.27
High Growth Scenario		0.06	0.24	0.67
Low Growth Scenario		0.05	0.13	0.27

In the transportation sector, a substantial increase in electricity demand can be achieved by transitioning to electric vehicles. By completely shifting all public and private vehicles to electric by 2050, along with the introduction of electric trains for both passenger and freight transport in 2030, the electricity demand is projected to escalate significantly. By the year 2030, the implementation of these measures is estimated to create an additional electricity demand of about 2442 GWh. This demand is expected to further rise to 5505 GWh by 2040 and substantially increase to 11513 GWh by 2050. The focus on electrifying both public and private vehicles play a crucial role in promoting sustainable and eco-friendly transportation practices. Encouraging the adoption of electric vehicles in public transportation, such as buses and trains, can lead to a noticeable reduction in greenhouse gas emissions and air pollution.

5.5.4 Financial Analysis

5.5.4.1 Electric Bus

Considering, the initial investment, infrastructure cost, annual repair and maintenance expenses, and annual fuel costs for both diesel and electric buses for 15 years, it is projected that the total cost of owning a diesel bus will surpass that of an electric bus after approximately 6.04 years. This means that the electric bus becomes economically more suitable compared to the diesel bus after this breakeven period, assuming normal tax rates of 85%, including excise and custom duty tax. However, when tax rates are reduced to 60% and 40%, the breakeven point is significantly reduced. In these scenarios, the electric bus becomes economically viable after 3.14 years and 2.26 years, respectively. This indicates that with reduced tax burdens, the electric bus becomes a more financially attractive option in a much shorter timeframe compared to the normal tax scenario.

Table 5-22: Financial Analysis of Electric Bus over Diesel Bus

Financial Parameters	Tax Rate		
	85%	60%	40%
Net Present Value (USD)	76,007,318	89,308,669	99,949,750
Internal Rate of Return	20%	30%	53%
Breakeven Period (Years)	6.04	3.14	2.26

5.5.4.2 Electric Car

The financial analysis comparing electric cars to non-electric (diesel/petrol) cars demonstrates that the electric car becomes economically viable after an investment period of 4.61 years, given the current tax rate of 40%. However, if the tax rate is reduced to 30% and 20%, the breakeven point for electric cars decreases to 3.91 years and 3.14 years, respectively, making the electric car a financially attractive option in a shorter timeframe when compared to non-electric cars.

Table 5-23: Financial Analysis of Electric Car Over Non-Electric Car

Financial Parameters	Tax Rate		
	40%	30%	20%
Net Present Value (USD)	8,039,262	8,461,105	8,882,948
Internal Rate of Return	27%	32%	39%
Breakeven Period (Years)	4.61	3.91	3.14

5.5.4.3 Electric Two Wheelers

The financial analysis comparing electric two-wheelers, specifically electric motorcycles, to petrol motorcycles demonstrates that the electric option becomes economically viable after an investment period of 4.49 years, assuming the current tax rate of 25%. However, if the tax rate is reduced to 20% and 10%, the breakeven point for electric two-wheelers decreases to 4.23 years and 3.67 years, respectively. This reduction in the breakeven point makes the electric two-wheeler a financially attractive choice in a shorter timeframe compared to non-electric motorcycles.

Table 5-24: Financial Analysis of Electric Two Wheelers over Petrol Two Wheelers

Financial Parameters	Tax Rate		
	25%	20%	10%
Net Present Value (USD)	703,337	737,459	805,704
Internal Rate of Return	23%	25%	30%
Breakeven Period (Years)	4.49	4.23	3.67

5.6 Construction & Mining (C & M) Sector

5.6.1 Baseline Information

The table displays various parameters concerning electricity demand in the construction and mining sectors. The fundamental data reveals that there has been relatively modest growth in electricity demand within these sectors compared to other industries. Over the last two decades, the electrical intensity in construction and mining has decreased. This reduction can be attributed to the sluggish increase in electricity demand when compared to the sector's Gross Value Added (GVA) growth.

Table 5-25: Overview of Construction and Mining sector Electricity Demand

Description	2001	2021	CAGR
C & M GVA (Million NRs) (2010-11)	76245	184231	4.51%
C & M Electricity Demand (GWh)	0.83	1.47	2.90%
C & M Electricity Share	0.0648%	0.0201%	-5.69%
C & M Electricity Intensity (kWh/NRs)	0.0109	0.0080	-1.54%

5.6.2 Electricity Demand

The In the base year, the electricity consumption of the construction and mining sector was 1.47 GWh. However, in the electrification scenario, this consumption is projected to increase significantly to reach around 1484 GWh by the year 2050. Remarkably, this represents a substantial 243% higher electricity demand compared to the business-as-usual scenario under the same growth assumptions. This notable difference in electricity demand is primarily due to the availability of numerous electrification options, which have driven the sector's increased reliance on electricity. During the base year, electricity covered only a negligible portion of the energy needs in the construction and mining sector. However, with the electrification efforts, the electrical intensity is expected to rise to 0.656 kWh per unit of output (NRs.) in the future, signifying a shift towards greater utilization of electricity in this industry. The electricity demand is projected to experience a notable increase, driven by a significantly higher Compound Annual Growth Rate (CAGR).

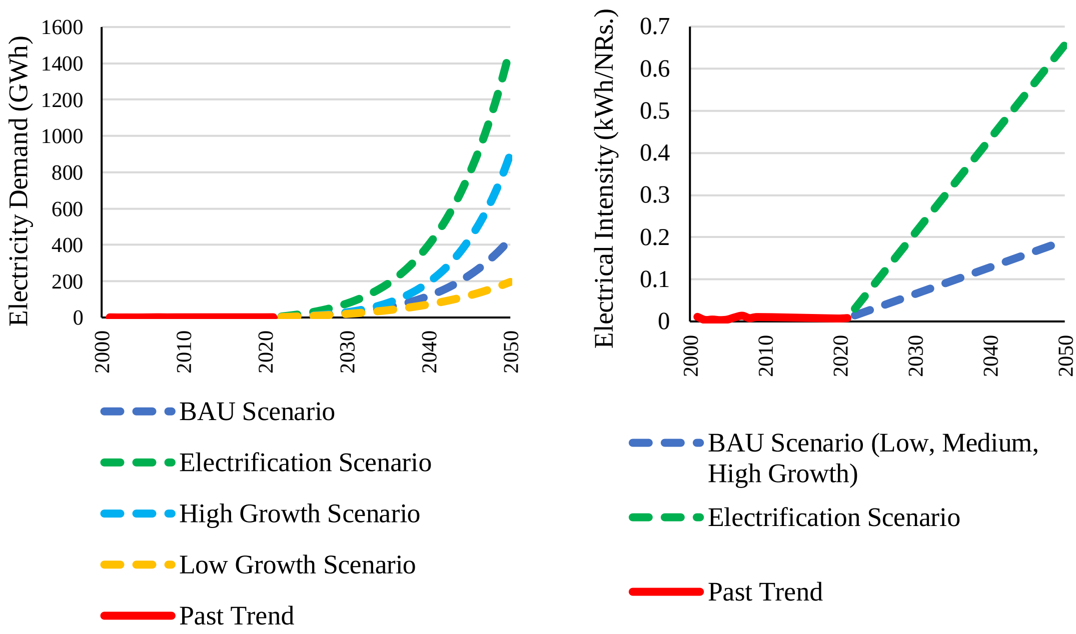

Figure 5-9: Electricity Demand in Construction and Mining Sector

This surge can be attributed to the rapid growth trend in construction activities observed in recent years. Moreover, there has been a notable increase in electrification efforts within the construction and mining sectors, leading to a substantial rise in their electricity consumption.

Table 5-26: Electricity Demand Projection in Construction and Mining sector

Description	Low Growth	Medium Growth (BAU)	Medium Growth (Electrification)	High Growth
C & M Electricity Demand, 2021 (GWh)	1.47			
C & M Electricity Demand, 2030 (GWh)	19.8	24.0	77.1	28.6
C & M Electricity Demand, 2040 (GWh)	72.1	118.5	399.7	194.2
C & M Electricity Demand, 2050 (GWh)	196.0	433.3	1,483.8	900.2
CAGR of Electricity Demand, 2021-2050	18.38%	21.66%	26.94%	24.77%
CAGR of Electrical Intensity, 2021-2050	5.07%	5.07%	6.42%	5.07%

5.6.3 Priority End Use

The construction and mining sectors heavily rely on large and powerful equipment, and much of their operations are carried out in rural or remote areas where electrification is challenging due to lack of electricity grid in rural areas. As a result, it is not feasible to achieve complete electrification or a complete shift to electric equipment in these sectors within the next twenty to thirty years. Due to these limitations, the electrification scenario assumes only about 25% of equipment will be electrified, while the majority will continue to use conventional non-electric methods.

CHAPTER SIX: BARRIERS AND BOTTLENECK

While transitioning to a more electricity-dependent economy is an important goal for reducing carbon emissions and promoting sustainable development, there are several bottlenecks and barriers which impede the transition in different sectors.

Table 6-1: Barriers for electricity demand creation

<table>
<tr><th>Policies and Governance Barriers</th><th>Infrastructure and Markets Barriers</th><th>Financial Barriers</th><th>Socioeconomic Barriers</th></tr>
<tr><td rowspan="2">Limited organization body</td><td>Infrastructure and technological issues</td><td>High-cost of investment</td><td rowspan="3">Behavioral issues</td></tr>
<tr><td>Limited stability and reliability of electricity supply</td><td rowspan="2">Under investment in electrical infrastructure</td></tr>
<tr><td>Communication gap between regulatory bodies</td><td>Last mile connectivity challenge</td></tr>
<tr><td>Weak policies</td><td>Lower internal production of technologies</td><td>Lower affordability on end use</td><td>“Not in My Backyard” psychology</td></tr>
</table>

6.1 Policies and Governance Barriers

The following are the specific policies and governance barriers hindering electricity demand creation in Nepal.

a. **Limited organization Body:** Nepal Electricity Authority is the sole actor for the transmission and distribution of electricity in Nepal and generally the presence of a single organization in supplying services is considered as hindering factor for creating and supplying good quality services due to the lack of competition organization (Blechinger et al., 2015).

b. **Communication gap between regulatory bodies:** Although different organizations are working on increasing electricity generation and consumption, there is a lack of coordination and clarity between them. In Nepal, multiple government agencies are responsible for different aspects of electricity generation and distribution. For instance, the Ministry of Energy, Water Resources and Irrigation oversees policy formulation, while the Nepal Electricity Authority (NEA) is responsible for electricity generation, transmission, and distribution. Additionally, there are several other organizations and development partners involved in the energy sector, each with its own priorities and objectives. The lack of a cohesive strategy and coordination mechanism often leads to overlapping efforts, inefficient resource allocation, and conflicting policies.

c. **Weak Policies:** In the context of Nepal, the weak and unclear policies regarding the registration of electric equipment, particularly electric vehicles (EVs), have posed challenges for investors and developers in the sector. This situation has resulted in lower market penetration of EVs in the country. One of the key issues is the lack of well-defined and consistent policies related to the registration and operation of electric vehicles. Uncertainty surrounding the registration process, including the requirements, procedures, and fees, can discourage investors and developers from entering the market. Without clear guidelines, it becomes difficult for businesses to plan and make informed decisions regarding the production, import, and distribution of electric vehicles.

6.2 Infrastructure and markets

The following are the specific infrastructural and market barriers that have affected the electricity demand creation in Nepal.

- **Infrastructural and technologies issues:** The infrastructure includes power transformers, voltage regulators, circuit breakers, switchgear, capacitors, fuses, controls, arresters, and conductors, which make the environment and the use of electricity safe as they can't produce harmful gases or chemicals. At the time of a short-circuit, the circuit breakers itself will break, causing less hazard to the person, house or any factory. The transmission and distribution networks in Nepal are not sufficient to meet the growing demand for electricity. The infrastructure is often outdated, poorly maintained, and unable to handle the load, leading to power losses and frequent disruptions. Nepal lags behind other countries in adopting new technologies for electricity generation, transmission, and distribution. This limits the efficiency and reliability of the system and makes it more vulnerable to external shocks. For the higher demand of electricity more infrastructure and accessories are needed to maintain a proper supply of energy, these infrastructures and accessories includes additional transmission lines, transformers, distribution center, power house etc. Also, in transport sector lack of charging station, EV friendly road, and infrastructure needed for electric vehicles causes low courage to new customers who want to shift to electric vehicle.
- **Limited stability and reliability of electricity:** Topography challenge and lack of switching option crates issues during failure in transmission and distribution system. It is crucial to make sure that the environment and natural resources are not harmed as power demand and supply rise. Supply should be raised in response to rising demand. The ecosystem and biodiversity are impacted during the construction of hydropower facilities. Therefore, careful planning and

investment should be made to minimize environmental deterioration and resource loss.

- **Last mile connectivity challenge:** Due to the topography of the country, the accessibility of large electric-intensive technology in rural areas can be a challenge. The diverse and rugged terrain, which includes mountains, hills, and remote regions, presents obstacles for the deployment and operation of electric-intensive technologies, such as large-scale industrial machinery and equipment. The difficult terrain and limited road connectivity make it challenging to transport heavy machinery and equipment to remote rural areas. The absence of well-maintained roads, bridges, and transportation networks increases the logistical difficulties and costs associated with bringing electric-intensive technology to these locations.
- **Lower internal production of technologies:** Lack of production and development of electrical appliances within the country can create an unnecessary burden for imports of electric equipment, although few industries are manufacturing electric equipment in Nepal products are not enough to fulfill the demand as well as only a few categories of product are being manufactured in Nepal.

6.3 Financial factors

The financial aspects associated with electricity demand creation is a major barrier. Some of these aspects are explained below.

- **High Investment cost:** A developing country like Nepal has difficulties in maintaining adequate electricity supply to create demand Due to high-cost investment in hydropower or other sector of renewable electricity (Blechinger et al., 2015). Also, the cost of establishing new electricity-intensive infrastructure is high.
- **Under-investment in electrical infrastructure:** Second Nationally Determined Contribution targets the electricity generation of 15,000 MW by 2030 but two third is dependent on foreign aid
- **Lower affordability in end use:** In Nepal, especially in rural areas where people's incomes are lower, there are a lot of poor individuals. They could struggle to pay their electricity payment. Additionally, electrical appliances like induction stoves and heaters cost more up front than biomass and firewood do. They will have to pay for both the initial cost of the appliances and the electricity bills. Consequently, they won't be able to pay it easily.

6.4 Socioeconomic factors

Some of the socioeconomic factors that impede the electricity demand creation in Nepal are explained below.

a. **Behavioral issues:** Some individuals, particularly those who live in rural areas, rely, etc. This is a result of the intertwining of social and cultural effects, as well as a lack of knowledge significantly on conventional cooking and heating techniques, such as utilizing firewood and biomass about the advantages of using electricity, which is far cleaner and more efficient and also the lack of awareness about health issues that is caused due to emission of harmful gases emitted from firewood and biomass. These individuals might therefore be averse to change and want to continue with conventional practices.

b. **"Not in my Backyard" psychology:** Generally, people prefer renewable energy but oppose development of electric production, distribution or transmission system near their localities due to environmental impact and safety concerns (Seetharaman et al., 2019) (Nasirov et al., 2015).

CHAPTER SEVEN: IMPLEMENTATION PLAN

7.1 Short Term Implementation Plan

Various short term implementation plan for different sectors which is expected to completed in period of 1- 5 years (By 2025) are presented:

Table 7-1: Short Term Implementation Plan

Economic sector	Action	Activities	Target duration	Responsible agency
Agricultural Sector	Awareness	Create an awareness programmed for the farmers and entrepreneurs regarding the use of electric technology	1-2 years	MoALD/ WECS/AEPC
	Promotion of Electric Technology	Regulate the lending of the electric technology like electric threshers and trillers	2-3 years	Local levels
	Subsidies	Focus on the promotion of water pump for irrigation in subsidies or subsidies less than 5%	4-5 years	Local Level
	Electrification	Shift to 50% electric water pump technologies	By 2025	MoALD, GoN
		Shifting to 15% electric thresher equipment		
		Penetration of electricity on 15% of tillage equipment		
Commercial Sector	Awareness	Create awareness program for commercial entities regarding the electricity tariff and demand management	2-3 years	WECS/AEPC/ Universities

Economic sector	Action	Activities	Target duration	Responsible agency
	Promotion of Electric Technology	Mandate the energy audit and implementation of the energy audit recommendations to create a way toward electric technology	3-5 years	MoEWRI/ MoICS
	Subsidies	Provide 5% or less subsidies on commercial cooking technologies	4-5 years	MoF, Local Levels
	Electrification	Penetrate electricity to 14-16 % of cooking technologies in different commercial subsector	By 2025	NEA, WECS, AEPC
Industrial Sector	Promotion of Electric Technology	Mandate the energy audit and its implementation	2-4 years	MoEWRI/ MoICS
	Subsidies	Promote electric technologies like electric furnace and electric boiler on industrial on 5% or less subsidy program	3-5 years	MoICS
	Electrification	Penetrate electrical technologies to 15% of furnaces, 52.5%motors in cement and brick industries	By 2025	NEA, MoICS, WECS
		Penetrate electrical technologies in 50% of furnaces, 32%motors and 15% of boilers in rubber and chemical factories		
		Penetrate electrical technologies in 25 % of		

Economic sector	Action	Activities	Target duration	Responsible agency
		furnaces, 46 % of motors and 15% of boilers in the food and beverage industries		
		Penetrate electrical technologies in 25 % of furnaces, 52% of motors ad compressors in steel and metal working industries		
		Penetrate electrical technologies in 16 % of furnaces, 85% of motors and 35 % of boilers in wood and paper industries		
		Penetrate electrical technologies in 17 % of furnaces, 64% of motors, and 15 % of boilers in textile industries		
		Penetrate electrical technologies in 22 % of furnaces, 95.2% of motors, and 15.5 % of boilers in other types of industries		
Residential Sector	Awareness	Conduct awareness programs at local levels especially targeting indigenous peoples and women to switch to electrical technology	2-3 years	WECS/AEPC/ Universities
	Electricity Regulation	Develop guidelines for the owning the electric meters for rented households	2-3 years	NEA

Economic sector	Action	Activities	Target duration	Responsible agency
	Subsidies	Provide 5% or less subsidies on Residential cooking technologies	3-5 years	AEPC, WECS, MOEWRI
	Electrification	Enforce11.7% of household to use electric cooking technologies	By 2025	NEA, WECS, AEPC
Transport Sector	Awareness Program	Mass awareness campaign to promote e-mobility	2-3 years	MoPIT/AEPC/WECS
	Feasibility Study	Assess the feasibility of cable cars and ropeways as a means of daily transportation	4-5 years	WECS/NEA
	Tax Deduction	Ensure Slightly decrement or no tax increment in electric buses, electric cars and electric two-wheelers	4-5 years	MoF, DoTM
	Electrification	Penetrate electricity to 25% of public passenger vehicles	By 2025	DoTM, WECS, NEA
		Penetrate electricity to 30% private passenger vehicles		
		Penetrate electricity to 7% freight vehicles		

7.2 Medium Term Implementation Plan

Various medium-term strategies to generate higher electricity demand in different economic sectors, with a completion goal within the next decade (by 2030), are outlined as follows:

Table 7-2: Medium Term Implementation Plan

Economic sector	Action	Activities	Target durati on	Responsible agency
Agricultural Sector	Infrastructure development	Improve the electric connectivity of farms	5-8 years	NEA
		Develop safety standards for the use of electric technologies	5-6 years	NEA
	Promotion of Electrical technologies	Penetrate the electrical technology in animal husbandry and fishing for temperature and humidity regulation	5-7 years	WECS, MoALD
	Subsidies	Provide 20% Subsidies on electric water pump for irrigation	6-7 years	Local Levels, MoF, WECS, MoALD
	Electrification	Penetrate 50% electricity on water pump, 30% electric technologies in farm machineries	By 2030	NEA, WECS, MoALD
Commercial Sector	Benchmarkin g Technologies	Prepare the benchmark for electricity use in different commercial subsectors	3-5 years	MoICS/FNCCI
	Subsidies	Provide 20% Subsidies on commercial cooking technologies	4-5 years	MoF, Local Levels
	Electrification	Penetrate 31-33 % of electricity in cooking technologies in different commercial subsector	By 2030	NEA, WECS, AEPC, private Sectors, Different Commercial Institutions
Industrial Sector	Infrastructure development	Improve the infrastructures including the transmission and distribution system to improve the voltage stability, reliability for use of energy intensive solution	5-7 years	NEA
	Infrastructure development	Promote the establishment of the new electric intensive	6-7 years	MoICS

Economic sector	Action	Activities	Target durati on	Responsible agency
		industry like fertilizer industry, green bricks industry		
	Policy making & Planning	Prepare a framework for easy import of the electrical technologies in the country	5-6 years	MoICS/DoC
		Develop a guidelines and standards for different productive end use (PEU in the industry)	5-6 years	WECS/RETS
		Develop a guideline to penalize the industry for the use of inefficient electrical technology	5-6 years	MoICS
	Incentives for electric technologies	Engage the industries in different incentives of switching to electric technology including carbon trading	6 years	MoFE
	Subsidies	Provide 20% subsidies on electric furnaces and electric boilers for industrial purpose	6-8 years	MoICS
	Electrification	Penetrate electricity to 31 % of furnaces, 62 % of motors in cement and brick industries	By 2030	NEA, MoICS, WECS
		Penetrate electricity to 60% of furnaces, 46 % of motors and 32 % of boiler in rubber and chemical factories		
		Penetrate electricity to 40% of furnaces, 57 % of motive power and 32 % of boilers in food and beverage industries		
		Penetrate electricity to 40 % of furnaces, 61% of motors		

Economic sector	Action	Activities	Target duration	Responsible agency
		and compressors in steel and metal working industries		
		Penetrate electricity on 32.5 % of furnaces, 88% of motors, 48 % of boilers in wood and paper industries		
		Penetrate electricity on 33% of furnaces, 71 % of motors, and 32 % of boilers in textile industries		
		Penetrate electricity to 37 % on furnaces, 96 % on motive power and 31% on boilers in other miscellaneous types of industries		
Residential Sector	Detailed Study & planning	Prepare the demand creation plan at provincial and local levels	6-7 years	WECS
		Develop one projects targeting the Paris Agreement through the promotion of cooking technologies	7-8 years	MoFE
	Subsidies	Provide 20% subsidies in residential cooking technologies	6-7 years	WECS, NEA, AEP
	Electrification	Enforce 25% of household to use electric cooking	By 2030	
Transport Sector	Infrastructure development	Benchmarking the standards of the charging stations	5-7 years	WECS/NEA
		Establish repair and maintenance center for electric vehicles	6-7 years	VTS/MoPIT/ Private Sector
	Planning & Policy making	Develop plans for transitioning medium- duty (MDV), heavy-duty (HDV)	6-9 years	WECS/ MoPIT, DoTM

Economic sector	Action	Activities	Target durati on	Responsible agency
		and transit vehicles to zero emission vehicles (ZEVs)		
	Tax deduction	Reduce tax to 60% (total of custom duty and excise tax) on electric buses	6-8 years	DoTM, Department of Custom, MoF, MoCIS
		Reduce tax to 30% on electric cars		
		Reduce tax to 20% tax on electric two wheelers		
	Electrification	Penetrate 50% electricity on public passenger vehicles	By 2030	WECS, DoTM, NEA, MoPIT
		penetrate electric technologies to 65% of private passenger vehicles		
		Introduce two passengers and one freight electric train operation in 200km of railway line		
		Penetrate electricity to 15.5% on freight vehicles		

7.3 Long Term Implementation Plan

Various long-term strategies to generate higher electricity demand in different economic sectors, with a completion goal within the next two and half decade (by 2050), are outlined as follows:

Table 7-3: Long Term Implementation Plan

Economic sector	Action	Activities	Target duration	Responsible agency
Agricultural Sector	Subsidies Program	Mobilize different funds for subsidizing the use of electric pumps and harvesters in the agriculture sector	15-25 years	AEPC/ WECS/MoF

Economic sector	Action	Activities	Target duration	Responsible agency
		Provide 50% subsidies on the water pump for Irrigation	15-25 years	AEPC/ WECS/MoF
	Electrification Program	Penetrate electricity to 60% of water pump	By 2050	NEA, MoALD, WECS
		Use 100% electric farm Machineries		
Commercial Sector	Incentives and Subsidies	Establish a provision for green labeling of the institutions and provide various incentives for the green labeled institutions	12-18 years	MoICS/ MoEWRI
		Develop a one stop solution to access soft loan and subsidy for switching to electric technology	12-18 years	MOEWRI/ WECS
		Provide 50% Subsidies to electric cooking technologies for commercial sector		
	Electrification Program	Electrify all cooking application in all commercial sub sectors	By 2050	NEA, WECS, MoICS
Industrial Sector	Decrease use of Fossil fuel technology	Increase the taxes on different inefficient technologies and fossil fuels	12-20 years	NoC/MoF
	Energy audit	Implement systems for monitoring and reporting of the energy consumption	10-20 years	WECS
		Prepare and implement a guideline with incentives for the old inefficient technologies	10-20 years	WECS

Economic sector	Action	Activities	Target duration	Responsible agency
		with the latest electrical technology		
	Subsidies Program	Provie 50% subsidies for electric furnace and electric boiler in industrial application	10-20 years	WECS, MoICS, MoF
	Electrification Program	Shifting to 100% electricity for industrial furnace and industrial boiler	By 2050	NEA, WECS, MoICS, MoF
Residential Sector	Decrease use of Fossil fuel technology	Remove subsidy on LPG gas for cooking	After 2035	NoC
	Subsidies Program	Provide 50% subsidies for electric cooking technologies for households	15-20 years	AEPC, MoF, WECS
	Electrification Program	Shift to 100% electricity for cooking application	By 2050	AEPC, NEA, WECS
Transport Sector	Infrastructure Development	Install the charging stations in different highways of the country	12-20 years	NEA/WECS
	Promotion of electrical vehicle	Promote the use of electric bus rapid transit in different highways	9-15 years	WECS/ MoPIT
	Tax Deduction	Reduce tax to 40% (total of Custom duty and excise tax) on electric buses	12-20 years	DoTM, Department of Custom, MoF, MoCIS
		Reduce tax to 20% on electric cars		

Economic sector	Action	Activities	Target duration	Responsible agency
		Reduce tax to 10% tax on electric two wheelers		
	Electrification Program	Penetrate 100% electricity on public passenger vehicles	By 2050	WECS, DoTM, NEA, MoPIT
		penetrate electric technologies to 100 % of private passenger vehicles		
		Penetrate electricity to 50% on freight vehicles		
Construction and Mining Sector	Feasibility Study	Develop the roster with the electric intensive technology that can be penetrated into construction and mining sector	9-20 years	WECS/NEA

CHAPTER EIGHT: CONCLUSIONS

Following conclusions has been drawn from the comprehensive analysis of Nepal's energy landscape, based on data from government bodies and their published reports, yields valuable insights for energy planning and policymaking.

- Among different scenario assumed on basis of different policy documents, different growth assumptions, the electrification scenario presents a transformative vision, projecting a substantial increase in electricity demand across sectors, with electricity contributing approximately 80.7% of total energy demand by 2050, a remarkable shift from the base year's 4.2%. The projected electricity demand in various scenarios for 2050 is as follows: 64 TWh (low growth), 126 TWh (medium growth business as usual), 210 TWh (medium growth electrification), and 241 TWh (high growth). These projections align closely with previous forecasts from WECS (Water and Energy Commission Secretariat) and NEA (Nepal Electricity Authority), and the generation forecast indicates sufficient capacity to meet the projected demand. The analysis reveals promising prospects for electrification within specific sectors. In the agricultural sector, electricity demand is expected to grow substantially, particularly in water pumping for irrigation, with a robust Compound Annual Growth Rate (CAGR) of 10.2%. This leads to an additional electricity demand of 1169 GWh compared to the business-as-usual scenario for medium growth in agricultural pumping. The financial analysis demonstrates the economic viability of investing in electric pumps, with a payback period of around 6 years in a scenario without subsidies and reduced to 5 and 2.45 years with subsidies of 20% and 50%, respectively. The Internal Rate of Return (IRR) for different cases exceeds 14%. Similarly, the commercial sector shows promising growth potential in electricity demand, with a forecasted demand 85% higher than the business-as-usual scenario. Electric cooking in the commercial sector is expected to create additional electricity demand of 20 TWh by 2050, with a strong CAGR of 28.09% compared to the business-as-usual scenario's CAGR of 26.87%. The financial analysis demonstrates a payback period of approximately 2.06 years for electric cooking in the commercial sector, which further decreases with subsidies.
- In the industrial sector, electrification is projected to lead to a 45% increase in electricity demand compared to the business-as-usual scenario. Prioritizing electric furnaces and boilers would create additional electricity demand of 27 TWh and 5 TWh, respectively. The financial analysis indicates payback periods of 8.33 and 8.66 years for electric furnace and boiler investments over a 15-year analysis period, with improvements when subsidies are increased. In the residential sector, electrification is expected to drive a significant 71% increase

in electricity demand compared to the business-as-usual scenario. Full electrification of cooking activities is estimated to create an additional electricity demand of 11 TWh by 2050. The financial analysis for residential electric cooking shows a payback period of 2.36 years over a 5-year analysis period, which reduces with subsidies. The transport sector offers a remarkable opportunity for electrification, with projected electricity demand over 265 times higher than the business-as-usual scenario. Financial analyses confirm the economic viability of electric buses, cars, and two-wheelers, with payback periods of 6, 4.6, and 4.5 years, respectively, and further improvements with subsidies and tax deductions. While the report underscores the immense potential of electrification, it emphasizes the importance of grid expansion and infrastructure development, especially in rural areas, to ensure successful implementation. Collaborative efforts between the government and stakeholders are crucial for realizing the benefits of electrification.

- Furthermore, the document outlines a comprehensive set of implementation plans, categorized into three-time frames: long term, medium term, and short term, based on their respective completion timelines. These plans encompass various strategies to promote electrification, enhance electricity consumption through increased utilization of electric technologies, and create awareness among stakeholders. Additionally, the plans include initiatives to promote electricity technology, develop existing infrastructure to meet higher demand, and strategize subsidy implementation to facilitate the transition to electric alternatives.
- The government of Nepal should prioritize policies promoting electrification and the adoption of electric technologies across sectors. Emphasizing sustainable energy practices will enable the country to meet its growing energy demands while contributing to global efforts in addressing climate change. The comprehensive analyses, with meticulous incorporation of numerical values and data, provide a strong foundation for informed decision-making, fostering a greener and more sustainable energy future for Nepal with higher electricity consumption in future.

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ANNEX

Past Trend of HDI and Electricity Consumption Per Capita of Nepal

S.N.	Year	HDI	Electricity consumption per capita
1.	1990	0.378	35.68
2.	1995	0.41	40.35
3.	2000	0.446	57
4.	2005	0.475	76.09
5.	2010	0.529	103.09
6.	2015	0.566	141.25
7.	2016	0.569	179.46
8.	2017	0.574	205.79
9.	2021	0.602	239.72
10	2022	0.602	304.44

Population and Household Growth (2021 to 2050)

Year	Population (Million)	Household		
		Low	Medium	High
2021	29.16	6,660,841	6,660,841	6,660,841
2022	29.56	6,758,724	6,759,249	6,759,903
2023	29.92	6,847,534	6,851,337	6,853,925
2024	30.27	6,936,709	6,943,858	6,949,068
2025	30.61	7,025,859	7,036,427	7,044,959
2026	30.96	7,114,699	7,128,754	7,140,681
2027	31.30	7,202,353	7,219,978	7,235,383
2028	31.63	7,288,698	7,309,974	7,328,940
2029	31.95	7,373,698	7,398,704	7,421,312
2030	32.27	7,457,398	7,486,210	7,512,538
2031	32.58	7,539,916	7,573,312	7,605,477
2032	32.89	7,621,443	7,659,514	7,697,642
2033	33.19	7,702,232	7,745,069	7,789,286
2034	33.49	7,782,598	7,830,293	7,880,726
2035	33.80	7,862,908	7,915,554	7,972,333
2036	34.10	7,943,579	8,002,011	8,063,808
2037	34.40	8,025,071	8,089,405	8156,325
2038	34.71	8,107,879	8,178,239	8,250,393
2039	35.02	8,192,533	8,269,049	8,346,556
2040	35.35	8,279,588	8,362,399	8,445,386
2041	35.69	8,369,618	8,458,563	8,546,713
2042	36.04	8,463,215	8,558,449	8,651,900

Year	Population (Million)	Household		
		Low	Medium	High
2043	36.40	8,560,977	8,662,671	8,761,574
2044	36.79	8,663,507	8,771,846	8,876,366
2045	37.19	8,771,405	8,886,592	8,996,909
2046	37.62	8,885,264	9,007,020	9,123,006
2047	38.07	9,005,662	9,134,212	9,256,072
2048	38.56	9,133,156	9,268,747	9,396,701
2049	39.07	9,268,278	9,411,176	9,545,465
2050	39.61	9,411,529	9,562,021	9,702,902

Elasticity of GDP and Population in Sectoral Growth

Sectors	Subsector	Elasticity	
		Population	GDP
Residential		1.04	0.02
Transport	Public	1.44	0.41
	Private	1.44	0.41
	Freight	0	0.6
	Air	0	1.54

Energy Demand in Different Scenario

(In PJ)

Scenario	2021	2025	2030	2035	2040	2050
BAU Scenario	625.6	626.2	692.0	789.5	977.4	1,603.8
Electrification Scenario	625.6	628.6	653.8	694.3	759.9	940.5
High Growth Scenario	625.6	640.6	749.4	963.4	1,347.7	2,881.6
Low Growth Scenario	625.6	609.4	638.5	672.0	745.1	950.9

Energy Demand in Low Growth Scenario

(In PJ)

Branch	2021	2025	2030	2035	2040	2050
Agriculture Sector	9.8	10.0	11.4	13.2	15.1	19.0
Commercial Sector	43.8	40.0	48.5	62.4	80.7	134.3
Industrial Sector	115.0	117.4	135.3	154.8	184.9	261.9
Residential Sector	395.2	371.0	357.9	338.8	340.5	349.8
Transport Sector	56.6	64.6	76.8	90.9	107.8	156.4
Construction and Mining Sector	5.2	6.3	8.7	11.8	16.1	29.4
Total	625.6	609.4	638.5	672.0	745.1	950.9

Energy Demand in Medium Growth Business as Usual Scenario

(In PJ)

Branch	2021	2025	2030	2035	2040	2050
Agriculture Sector	9.8	10.8	13.8	18.4	24.8	42.0
Commercial Sector	43.8	43.2	58.8	87.2	132.7	296.9
Industrial Sector	115.0	126.7	164.3	216.8	305.4	582.8
Residential Sector	395.2	371.5	359.3	341.1	343.9	355.4
Transport Sector	56.6	67.2	85.2	109.5	144.1	261.6
Construction and Mining Sector	5.2	6.8	10.5	16.5	26.5	65.1
Total	625.6	626.2	692.0	789.5	977.4	1,603.8

Energy Demand in Medium Growth Electrification Scenario

(In PJ)

Branch	2021	2025	2030	2035	2040	2050
Agriculture Sector	9.8	10.7	12.9	15.5	18.7	24.0
Commercial Sector	43.8	51.5	67.7	89.9	119.6	186.9
Industrial Sector	115.0	127.1	161.3	207.4	269.7	420.9
Residential Sector	395.2	375.1	342.6	296.5	243.7	118.6
Transport Sector	56.6	57.5	59.6	70.0	85.0	136.3
Construction and Mining Sector	5.2	6.6	9.8	15.0	23.3	53.8
Total	625.6	628.6	653.8	694.3	759.9	940.5

Energy Demand in High Growth Scenario

(In PJ)

Branch	2021	2025	2030	2035	2040	2050
Agriculture Sector	9.8	11.5	16.5	26.3	40.7	87.3
Commercial Sector	43.8	45.9	70.1	124.6	217.4	617.0
Industrial Sector	115.0	134.6	195.9	309.9	500.4	1,210.9
Residential Sector	395.2	372.0	360.5	343.6	347.3	360.7
Transport Sector	56.6	69.4	93.9	135.3	198.6	470.6
Construction and Mining Sector	5.2	7.3	12.5	23.6	43.4	135.2
Total	625.6	640.6	749.4	963.4	1,347.7	2,881.6

Electricity Demand in Different scenario

(In GWh)

Scenario	2021	2025	2030	2035	2040	2050
BAU Scenario	7,313	15,118	25,493	40,994	59,498	126,218
Electrification Scenario	7,313	14,615	28,201	49,122	82,225	210,773
High Growth Scenario	7,313	15,670	28,654	53,459	88,603	241,937
Low Growth Scenario	7,313	14,501	22,667	32,868	41,787	67,756

Electricity Demand in Low Growth Scenario

(In GWh)

Branch	2021	2025	2030	2035	2040	2050
Agriculture Sector	203	323	444	562	702	1,093
Commercial Sector	1,055	2,020	2,999	4,161	5,715	10,671
Industrial Sector	2,806	5,756	10,045	16,001	21,306	36,985
Residential Sector	3,246	6,391	9,151	12,094	13,976	18,780
Transport Sector	2	4	7	11	16	31
Construction and Mining Sector	1	7	20	40	72	196
Total	7,313	14,501	22,667	32,868	41,787	67,756

Electricity Demand in Medium Growth Business as Usual Scenario

(In GWh)

Branch	2021	2025	2030	2035	2040	2050
Agriculture Sector	203	349	539	784	1,154	2,417
Commercial Sector	1,055	2,178	3,637	5,809	9,401	23,587
Industrial Sector	2,806	6,179	12,099	22,159	34,689	80,658
Residential Sector	3,246	6,400	9,187	12,175	14,116	19,080
Transport Sector	2	4	7	12	19	43
Construction and Mining Sector	1	8	24	56	119	433
Total	7,313	15,118	25,493	40,994	59,498	126,218

Electricity Demand in Medium Growth Electrification Scenario

(In GWh)

Branch	2021	2025	2030	2035	2040	2050
Agriculture Sector	203	346	641	1,113	1,870	4,559
Commercial Sector	1,055	1,919	3,888	7,468	14,004	43,694
Industrial Sector	2,806	5,650	11,893	22,613	41,100	116,925
Residential Sector	3,246	5,758	9,253	14,022	19,328	32,555
Transport Sector	2	919	2,450	3,721	5,524	11,557
Construction and Mining Sector	1	23	77	186	400	1,484
Total	7,313	14,615	28,201	49,122	82,225	210,773

Electricity Demand in High Growth Scenario

(In GWh)

Branch	2021	2025	2030	2035	2040	2050
Agriculture Sector	203	370	642	1,121	1,891	5,022
Commercial Sector	1,055	2,314	4,335	8,304	15,402	49,008
Industrial Sector	2,806	6,565	14,421	31,677	56,836	167,588
Residential Sector	3,246	6,408	9,219	12,262	14,256	19,361
Transport Sector	2	4	8	14	24	58
Construction and Mining Sector	1	8	29	80	194	900
Total	7,313	15,670	28,654	53,459	88,603	241,937

Share of Electricity (of Total Energy demand) in Different Scenario

Scenario	2021	2025	2030	2035	2040	2050
BAU Scenario	4.2%	8.7%	13.3%	18.7%	21.9%	28.3%
Electrification Scenario		8.4%	15.5%	25.5%	39.0%	80.7%
High Growth Scenario		8.8%	13.8%	20.0%	23.7%	30.2%
Low Growth Scenario		8.6%	12.8%	17.6%	20.2%	25.7%

Baseline Information on Transportation Sector

Million Passenger-Km		
Sub Sector	Vehicle Type	2021
Public Transport	Bus	12,718.76
	Mini Bus	2,038.96
	Micro Bus	1,399.72
	Tempo	414.07
	E-Rikshaw	47.76
	Train	-
Private Transport	Car	3,270.12
	Jeep	640.52
	Van	1,517.44
	Two Wheelers	11,819.38
Million Ton-km		
Freight	Truck	.
	Mini Truck	111.84
	Tractor	639.97
	Pickup	1,477.06
	Cargo Van	33.58
	Train	-
Number of Passenger (Million)		
Aviation	Plane & Helicopter	7.87