BHUTAN
ENERGY DATA DIRECTORY 2022

Department of Energy
Ministry of Energy and Natural Resources

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2022

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FOREWORD

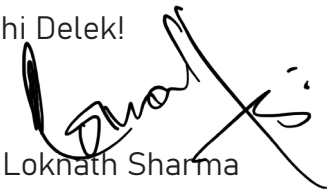
I am delighted to present the third edition of the Bhutan Energy Data Directory, a comprehensive and insightful resource that sheds light on the Energy Sector of Bhutan. This latest update, which includes data up to 2022, builds on the previous editions published in 2005 and 2015, providing an up-to-date and detailed overview of Bhutan's energy landscape.

The Directory reveals that Bhutan's total energy supply increased to 793,263.3 tons of oil equivalent (TOE), with thermal energy sources accounting for 62.4 percent of the energy mix and electricity contributing the remaining 37.6 percent. However, alternative renewable sources like the embedded hydro, solar and wind only accounted for less than 1 percent of electricity generation. This highlights the need for continued efforts to promote alternative renewable energy sources in Bhutan. It is encouraging to see that the Building Sector's energy consumption decreased, while the Industry Sector's energy consumption grew, and the Transport Sector's energy consumption declined.

The Bhutan Energy Data Directory is a valuable resource for policymakers, researchers, and anyone interested in the energy sector of Bhutan. It provides a wealth of data and information on various aspects of Bhutan's Energy Sector, including energy production, consumption, and distribution.

I would like to commend the team behind this Directory for their hard work and dedication in compiling this important resource. The data has been carefully collected, collated, and analyzed by experts in the field, ensuring its accuracy and reliability. I am confident that this Directory will be an invaluable resource in guiding policy decisions and shaping the future of Bhutan's Energy Sector. I hope that the insights presented in this Directory will inspire continued efforts towards a more sustainable and resilient energy future for Bhutan.

Tashi Delek!



HE Loknath Sharma
Minister of Energy and Natural Resources

ACKNOWLEDGEMENT

The Bhutan Energy Data Directory 2022 is an important initiative led by the Department of Energy, Ministry of Energy and Natural Resources, Royal Government of Bhutan, with financial assistance from Capacity Building Initiative for Transparency (CBIT)- FAO-GEF funding with the Department of Environment and Climate Change as the Project Management Unit under project document. The Report was prepared by consultants from Kuenden Statistical Services under the guidance and support of the Department's core team.

The core team consists of dedicated individuals who played a crucial role in the preparation of this Directory. They include Ms. Dechen Dema (Executive Engineer), Ugyen Chophel (Executive Engineer), Mr. Ugyen Rinzin (Engineer), Mr. Tandin Gyeltshen (Engineer) and Mr. Karma Tenzin (Jr. Engineer). Their expertise and commitment greatly contributed to the quality and accuracy of the data presented in the Report.

The Department of Energy would like to express deep gratitude to all the stakeholders who played a vital role in making this Energy Data Directory possible. The valuable contribution and support of organizations such as the Electricity Regulatory Authority, Bhutan Power Corporation Limited, Department of Forest and Park Services, Department of Geology and Mines, Department of Industry, Department of Revenue and Customs, Department of Trade, Druk Green Corporation Limited, National Statistics Bureau, Natural Resources Development Corporation Limited, Bhutan Construction and Transport Authority, World Wildlife Fund for Nature and others are highly appreciated.

Additionally, the Department would like to acknowledge the support and cooperation of all the survey respondents and focal persons who provided the necessary data. Their participation was crucial in ensuring the accuracy and comprehensiveness of the Directory. The efforts of the supervisors and enumerators involved in collecting the data are also recognized and greatly appreciated.

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ACRONYMS

ATF	Aviation Turbine Fuel
BAU	Business as Usual
BPC	Bhutan Power Corporation Limited
CAGR	Compounded Annual Growth Rate
CSI	Cottage and Small Industries
DGPC	Druk Green Power Corporation Limited
DoE	Department of Energy
DoI	Department of Industry
DoT	Department of Trade
EV	Electric Vehicle
GDP	Gross Domestic Product
HSD	High Speed Diesel
HV	High Voltage
DRC	Department of Revenue and Customs
LDO	Light Diesel Oil
LV	Low Voltage
MoAL	Ministry of Agriculture and Livestock
MoENR	Ministry of Energy and Natural Resources
MV	Medium Voltage
NRDCL	Natural Resource Development Corporation Limited
POL	Petroleum, Oil and Lubricants
PSU	Primary Sampling Unit
RE	Renewable Energy
SKO	Superior Kerosene Oil
SSU	Secondary Sampling Unit

LIST OF UNITS

GWh	Gigawatt hour
kW	Kilowatt
kl	Kilo litre
kV	Kilo Volt
kWh	Kilowatt hour
kVA	Kilo Volt Ampere
GJ	Gigajoule
M	Million
MW	Megawatt
MWh	Megawatt hour
Nu	Ngultrum
TOE	Tonnes of oil equivalent

EXECUTIVE SUMMARY

The Bhutan Energy Data Directory 2022 is a highly informative and timely analysis that provides a comprehensive understanding of Bhutan's energy supply and demand landscape. Through a meticulous combination of primary data collection and extensive secondary research, this Report offers valuable insights into energy consumption patterns across crucial sectors such as Building, Industry, Transport, and other sectors like Agriculture.

By delving into the intricacies of Bhutan's energy landscape, the Directory is intended to equip policymakers, researchers, and stakeholders with a valuable resource to enhance their understanding of the country's energy dynamics. This comprehensive overview serves as a roadmap for promoting energy sustainability and efficiency, guiding strategic decisions and initiatives aimed at advancing Bhutan's Energy Sector.

Energy Supply

Bhutan's energy supply primarily relies on electricity, fuel-wood, coal, and diesel. Electricity is the largest contributor, with a shift towards increased usage over the years. Fuel-wood usage has decreased, while bio-gas, solar energy, and limited-scale wind energy have gained traction as alternative sources. Bhutan is promoting cleaner and sustainable energy options to support its commitment to environmental conservation and sustainable development.

Bhutan's Hydropower Sector plays a crucial role in generating electricity, capitalizing on its abundant hydropower resources. The country has a considerable hydropower potential, estimated at 37,000 MW, of which 33,000 MW is techno-economically viable. The current installed capacity of 2334.1 (including 8.1 MW from embedded hydro generation) will increase to 4,672.1 MW with the completion of major projects like Nikachhu, Punatshangchhu-I and II, and three small hydro plants. The Tala Hydropower Plant is the largest in Bhutan, contributing 42.1 percent of the country's total electricity production in 2022.

Bhutan has been expanding its power exports, peaking at 9,186 GWh in 2020. However, in 2022, the exports declined to 7,240 GWh. Meanwhile, power imports have generally decreased over time, but increased to 204 GWh in 2022 from the previous year's 80 GWh.

Petroleum products: Bhutan relies on petroleum product imports from India due to the absence of domestic reserves or refineries. In terms of anthracite, there was no production or export of this coal variety in Bhutan during 2022. However, the country did import a small quantity of anthracite, specifically 0.22 MT. As for sub-bituminous coal, Bhutan imported 39,389 MT, while the export amounted to just 24.16 MT. It is noteworthy that both coal imports and exports, as well as unit exports, experienced a decline from 2014 to 2022. LPG consumption has slightly declined since 2020, while S.K Oil (Kerosene) consumption has consistently decreased over time. Kerosene (ATF)

consumption has fluctuated, notably with a significant decrease in 2021 (1,239 kl), but increased in 2022 (2,307 kl). Conversely, petrol consumption has shown minor variations with an increase 2022 (36,697 kl) from 2021 (33,331 kl), while diesel consumption has remained relatively stable with slight fluctuations.

Biomass: Fuelwood usage holds significant importance in Bhutan, particularly in rural areas where quantification is challenging. Urban regions rely on fuelwood supplied through the Natural Resource Development Corporation Limited (NRDCL) depots, with an estimated supply of 250,179.22 MT in 2022. To address fuelwood demand, Bhutan produces sawdust briquettes from waste wood and sawdust, offering an alternative fuel source. However, there was a notable decrease in briquette production, with only 132.39 MT produced in 2022, marking a 58 percent reduction as compared to 2014.

In rural households, small-scale biogas plants are a popular solution, with a potential for 20,000 plants. However, the key hurdle lies in ensuring households possess enough cattle to provide the required daily manure supply. Presently, Bhutan has 8,306 biogas plants, generating an estimated total of 6,116.9 MT of biogas per year.

Other Potential Renewable Energy Resources: Besides hydropower, other renewable energy sources, particularly solar, wind, and waste-to-energy resources have not been fully utilized despite their significant potential. The total restricted theoretical development potential of wind and solar power is estimated to be around 761 MW and 12,000 MW, respectively. Waste-to-energy techniques can effectively manage the country's daily 172,161 kg of solid waste, with the potential to produce up to 49.23 MWh per day, and household waste alone has a potential of 23.305 MWh.

Demand side

The energy consumption in Bhutan is analyzed across three main Sectors: Building, Industry, and Transport, with the remaining consumption attributed to other sectors including Agriculture.

Building Sector: Within the Building Sector, the consumption of electricity amounted to 502.44 GWh in 2022, with residential buildings accounting for 68.7 percent of this usage. The primary contributors to electricity consumption in residential buildings were space heating/cooling and cooking. Kerosene consumption in the Building Sector was 1,091.18 kl. For residential buildings and commercial and institutional buildings, it accounted for 948.48 kl and 142.20 kl, respectively. Overall, the total kerosene consumption decreased from 1,369.06 kl in 2014 to 1,139.56 kl in 2022, with a larger decrease observed in the institutional and commercial segment.

Regarding briquettes usage in the Building Sector, 47.42 percent were utilized for cooking purposes, while 52.58 percent were used for heating. The consumption of briquettes in the Sector declined from 316.15 MT in 2014 to 132.39

MT in 2022. Fuelwood consumption in the Building Sector was predominantly for cooking (36.2%), followed by other purposes such as rituals, hot stone baths, and art and crafts (41.3%), and heating (22.5%). The institutional and commercial segment consumed 42,768.02 MT of fuelwood.

Industry Sector: The Industry Sector is crucial to Bhutan's economy. Cottage and Small Industries (CSIs) account for 95 percent of total industries in the country. The majority of electricity consumed in the Industry Sector in 2022 was used by High voltage (HV) industries (91.7 %). The MV industries consumed 7.7 percent while the combined share of low voltage (LV) and CSI industries was only 0.6 percent. There was a significant increase in electricity and kerosene consumption in the industrial Sector, while diesel consumption showed steady growth. Sub-bituminous coal demand increased by 31.2 percent from 2014 to 2022 despite a decrease in demand from the MV industries and CSIs.

Transport Sector:
The Transport Sector in Bhutan heavily relies on diesel, petrol, and aviation turbine fuel (ATF), although there has been a recent introduction of electric and hybrid-electric vehicles, leading to the utilization of electricity as well.

In 2014, the consumption of petrol stood at 24,128.90 kl, and it rose to 34,575.57 kl in 2022. On the other hand, diesel consumption was 110,280.99 kl in 2014, decreasing to 88,131.36 kl in 2022. The consumption of ATF was 3,546 kl in 2014, declining to 2,122.21 kl in 2022. Notably, electricity consumption was merely 0.06 GWh in 2014 but experienced a substantial increase to 0.57 GWh in 2022.

To encourage the adoption of clean transportation, the government offers tax exemptions on electric vehicles. Analyzing fuel consumption data from 2014 to 2022, it is observed that petrol consumption had increased, while diesel and aviation turbine fuel consumption had decreased. However, there had been a significant growth in electricity consumption, highlighting the importance of promoting sustainable energy sources within the Sector.

CHAPTER

01

INTRODUCTION

1.1. Background

Bhutan is a small, emerging economy situated between China and India. The country is 38,394 sq. km in size with a population of around 770,276. The rate of GDP growth, after reaching a low of negative 10.1 percent in 2020 recorded a growth of around 4.09 percent in 2021 (NSB, 2022). Hydropower, cement, wood, and food products constitute the primary industries of Bhutan, with agriculture (19.2% of GDP), electricity and water supply (15.6% of GDP), and wholesale and retail trade (10.8% of GDP) comprising the major economic activities of the country.

Owing to its mountainous terrain, industrial and mechanized development has been slow and expensive. However, Bhutan recognizes the importance of energy for social development and poverty reduction through economic growth. The government has made significant efforts to increase rural electricity access, and hydropower is currently the main resource for electricity generation.

The availability of relatively abundant hydropower has also been an advantage for the country, as it generates significant revenue and helps balance trade deficits.

Bhutan has achieved a high rate of electrification, with over 99.5 percent of households connected to the grid (NSB, 2022b). Hydropower resources in Bhutan are mainly 'run-of-the-river' type and have low impact on the environment. Bhutan has surplus power during the summer months, but imports electricity from India during lean generation months.

Besides hydropower, Bhutan has sizable potential for solar and wind energy production, as well as for biomass and biogas. Although Bhutan has made significant progress in developing its renewable energy sector, there are still opportunities for further development. These include private sector involvement in renewable energy projects, energy efficiency measures to decrease energy demand, and stronger policies and regulations to encourage renewable energy development (IRENA, 2019).

The country primarily relies on hydro electricity and biomass such as fuelwood for residential energy needs, particularly in rural areas. Some industries and households also use fuelwood, woodchips, and briquettes. Imported fossil fuels, including kerosene and Liquefied Petroleum Gas (LPG), are used for cooking and heating in residential and commercial buildings, and petrol, diesel, and Aviation Turbine Fuel (ATF) are mainly used for transport. While heavy industries primarily rely on electricity, they have shown an increasing dependence on diesel and coal.

Biomass, mainly in the form of fuelwood, is used for residential energy needs, while imported fossil fuels, including petroleum products and coal, are used for the Transport and Building Sectors.

The Energy Data Directory is a crucial resource for understanding the Energy Sector in the country. This Directory is analyzed through three lenses, specifically energy supply, energy demand, and energy balance. It was first

developed in 2005 by the erstwhile Department of Renewable Energy, with the assistance of consultants from The Energy and Resources Institute, and was updated in 2015 by Ernst & Young LLP, with financial support from the Government of Norway and the Asian Development Bank, under the Energy Plus Programme: Clean Energy Development in Bhutan (DRE, 2015).

The Energy Data Directory 2022 is being updated with the most recent data to reflect the current energy scenario of the country. The Report is expected to provide useful information for all stakeholders to evaluate and understand the impacts of policy interventions in the Energy Sector. Further, it can be an important tool for making informed decisions to improve energy efficiency, reduce emissions, and ensure a reliable and affordable energy supply for all.

1.2. Laws and Policies on Energy Sector

The Electricity Act of 2001 serves as the regulatory framework for the Electricity Sector in Bhutan. However, some of its provisions have been replaced with the establishment of new institutions.

The Alternative Renewable Energy Policy 2013 encourages the use of alternative renewable energy sources besides hydropower such as solar, wind, embedded hydro, and biogas, in order to lessen the nation's reliance on fossil fuels and advance sustainable energy development (RGoB, 2013). It sets a number of goals, including boosting the use of renewable energy sources in grid-connected and off-grid locations, supporting private sector investment in renewable energy initiatives, and promoting energy efficiency and conservation measures.

The National Energy Efficiency and Conservation Policy 2019 strives to facilitate improvements in productivity and energy efficiency while contributing to sustainable development. The policy is comprehensive, covering several sectors such as Building, Transport, and Industry. It provides a crucial framework for promoting sustainable and efficient energy use in Bhutan, helping the country to achieve its goals of reducing greenhouse gas emissions and promoting sustainable economic growth (MoEA, 2019).

The Sustainable Hydropower Development Policy 2021 was formulated to ensure that hydropower development takes place in a manner that does not compromise macro economic stability or socio-environmental sustainability. Its primary objectives are to enhance energy security and develop value chains based on alternative clean energy sources. Given Bhutan's abundant renewable hydropower potential, the policy provides a crucial framework and guidelines for the sustainable development of this resource.

1.3. Institutional Structure

The Department of Energy (DoE), Ministry of Energy and Natural Resources (MoENR) serves as the central coordination agency and focal point of the Royal Government of Bhutan on energy related matters. It oversees the

development and operation of hydro-power projects as well as promoting the use of alternative renewable energy sources. The DoE also works to encourage energy efficiency and conservation measures, with the aim of ensuring that Bhutan's energy resources are used in a sustainable and environmentally responsible manner (Details in Appendix 1).

1.4. Study Methodology

The methodology used in this study is a combination of primary data gathering and secondary research. The study is focused on deriving energy consumption patterns in the major sectors of the economy: Building Sector; Industry Sector; and Transport Sector, and the remaining consumptions attributed to other sectors including Agriculture.

1.4.1. Primary Data Collection

Nationwide surveys were conducted to gather primary data on the volume, pattern, and major drivers of fuel consumption in different sectors.

As part of the methodology, a survey data collection protocol was developed which included the team's composition, contingency plans, systems for monitoring the interviewers, and interview schedule. Similarly, a quality assurance protocol was also developed that included the process of reviewing the questionnaires for consistency and accuracy by interviewing some of the respondents on key variables; and to check for any aberrations. Apart from the supervisors, the IT expert and the Team leader based in Thimphu monitored the data submitted on a day-to-day basis.

Building Sector: The Building Sector is divided into two segments: residential and commercial/institutional. To estimate the energy consumption in the residential segment, a comprehensive survey of 5,300 households across 20 *dzongkhag* was carried out.

The primary survey aimed to collect data on the volume and pattern of fuel consumption in the Building Sector, including the type of fuel used, the frequency of use, and the duration of use for each end-use.

The *chiwog* was the primary sampling unit (PSU) while households formed the secondary sampling unit (SSU) in rural areas. In the case of urban areas, the Enumeration Areas (EAs) formed the PSUs while the households in the selected PSUs formed the SSUs.

A multi-stage sampling procedure was adopted. In the first stage, certain numbers of PSUs (*chiwog* in rural areas and EAs in urban areas) were selected using probability proportional to the size without replacement and the number of households in a *chiwog* was the size variable. The households were selected based on systematic random sampling. The Survey was administered to the head of the household.

The Survey developed a context-specific sampling frame in consultation with the National Statistics Bureau. However, for the selected *chiwog* and the EAs, the household list was updated prior to the

survey enumeration. This exercise was carried out in consultation with the local administration. This updated list was used for sampling and generating weights during data analysis. The following formula was used to calculate the sample size:

$$N_h = \frac{(z^2)(p)(1-p)(f)(k)}{(e^2)}$$

where:

N_h = sample size in terms of number of households for each *dzongkhag*

z = statistic that defines the level of confidence desired (1.96)

p = an estimate of key indicator to be measured by the Survey (50%)

f = the sample design effect, assumed to be 4

k = a multiplier to account for anticipated rate of non-response (10%)

e = margin of error to be attained (4%)

Based on the above parameters, the sample size was 5,300 households (2,700 households in urban areas and 2,600 households in rural areas).

A purposive sampling method was adopted to select the commercial/ institutional units. It was ensured that at least two units to be selected in each *dzongkhag* included boarding school, non-boarding school, health facility, monastery, offices, and retail shops. From the target sample size of 1,693 units, the Survey successfully enumerated 1,515 units.

Industry Sector: Primary data was collected from 47 industrial units. The Survey collected data on fuel usage including coal, petroleum, and other fuels. However, the electricity consumption data was sourced from the Bhutan Power Corporation Limited (BPC) and the DoE.

Transport Sector: The collection of fuel consumption data involved the stationing of enumerators in each of the petroleum product distributors for a period of 10 days. During this time, the enumerators collected data on the amount of fuel refilled by each vehicle, as well as fuel purchased for other purposes such as household use and machinery. The vehicle population data was collected from the Bhutan Construction and Transport Authority (BCTA). The import data for petroleum fuel was collected from the DoT, Petroleum Oil and Lubricants (POL) stations, and the Department of Revenue and Customs (DRC).

1.4.2. Secondary Data Collection

Secondary research was also conducted on the publications from various government agencies and institutions which report on energy consumption. The secondary data was used to derive both aggregate energy demand and supply in each sector. Hydroelectricity generation, distribution, sale, and export data was sourced from the Druk Green Power Corporation Limited (DGPC) and the BPC. Petroleum import data was collected from the POL section, the DoT, and the

DRC through their annual publication – Bhutan Trade Statistics. Data on coal production in the country was collected from the Department of Geology and Mines (DGM). Data on firewood was collected from Natural Resources Development Corporation Limited (NRDCL) and the Department of Forests and Park Services (DoFPS). Data on Solar and Wind energy potential mapping and assessments were gathered from the DoE.

1.4.3. Analysis

The data collected through surveys and secondary research were analyzed using statistical tools and techniques to derive insights into the energy consumption patterns in each sector. The data was analysed using the STATA statistical software (version 17).

The sampling weight was used to derive the demand estimates in the Building Sector. Post-estimation technique was used to adjust for the total consumption. For the Industry Sector, the data from the enumerated industrial units was used to estimate fuel demand for the remaining industrial units based on the electricity data available for all industries. The fuel data collected from the POL stations helped derive the proportion of fuel demand for the Transport Sector.

1.4.4. Limitations

Although the Study used a comprehensive and data-driven methodology to estimate the energy consumption of major sectors in the economy, it has some limitations. Firstly, the energy consumption of the Building Sector was solely based on respondents' recall method, which might not provide adequate quantitative data on consumption patterns. Secondly, the data collection on fuel refill within the Transport Sector was only carried out for a 10-day period in a specific month and may not represent typical consumption patterns for the entire year. Thirdly, unlike heavy voltage (HV) industrial units, some industrial units from medium voltage (MV), low voltage (LV), and cottage and small industry (CSI) did not provide the required data which necessitated the Study to come up with estimates. Finally, data collection was carried out in 2022, which was not a typical year due COVID-19 which may have disrupted energy consumption patterns.

CHAPTER

02

ENERGY SUPPLY

In Bhutan, the primary sources of energy include electricity, coal, fuelwood, LPG, petrol and diesel. Among these, hydropower stands as the largest and most significant source of energy, while fuelwood remains prominent in rural areas. However, there has been a notable shift in recent years. The use of fuelwood has decreased considerably, while hydropower has witnessed a significant increase in utilization. Furthermore, promoting the use of biogas, particularly in rural areas, has led to a surge in the number of households using it as an energy source. Solar energy is also gaining footing as an alternative source of power, and though still at a limited scale, wind energy has been implemented in certain areas.

2.1. Electricity

Over the last ten years, there have been significant transformations in the Power Sector of Bhutan, both in its structure and policies, driven by ongoing reform processes. Bhutan has a substantial hydropower potential, which is estimated to be 37,000 MW. Out of this, 33,000 MW is considered to be techno-economically feasible.

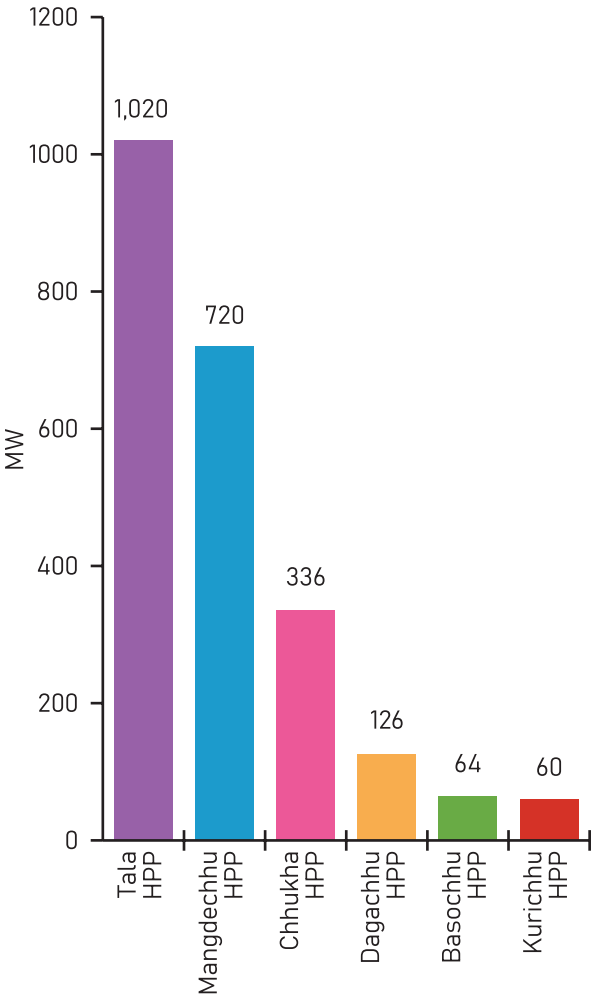
Currently, Bhutan's installed capacity stands at 2,344.35 MW. The majority of this capacity is derived from hydropower plants, accounting for 2,334.1 MW, including 8.1 MW from other embedded-hydro sources. In addition to hydropower, the country relies on diesel generators owned by Bhutan Power Corporation (BPC), contributing 8.93 MW to the overall capacity. Furthermore, the grid is connected to solar photovoltaic (PV) power plants with a capacity of 724 kWp and wind power plants with a capacity of 600 kW.

Notably, there are 3 major projects currently in progress: Nikachhu, Punatshangchhu-I, and Punatshangchhu-II. Once these projects are completed, they will add an additional 2,338 MW to the installed capacity. Moreover, there are 3 on-going small projects, namely Yunghichhu, Burgangchhu, and Suchhu, which will collectively contribute 104 MW. Consequently, the total installed generation capacity for the country will reach 4,786.48 MW.

2.1.1. Major Hydropower Generation Plants

The data presented in Figure 2.1 provides insights into the total installed capacities of 6 major hydropower plants, which collectively amount to 2,326 MW. The Tala Hydropower Plant has the highest installed capacity, generating an impressive 1,020 MW, while the Mangdechhu Hydropower Plant follows closely behind with a capacity of 720 MW. The remaining hydropower plants contribute to the energy landscape with the following capacities: Chhukha Hydropower Plant - 336 MW, Dagachhu Hydropower Plant - 126 MW, Basochu Hydropower Plant - 64 MW, and Kurichhu Hydropower Plant - 60 MW.

Figure 2.1: Installed Capacities of Major Hydropower Plants in 2022 (MW)



Source: BPC Power Data Book 2022

Below are descriptions of the six major hydropower plants in Bhutan:

Basochhu Hydropower Plant: The Basochhu Hydropower Plant is a two-stage project with a combined capacity of 64 MW. The Upper Stage harnesses the power of the Basochhu stream, generating 24 MW of power. The Lower Stage utilizes tail-race water from the Upper Stage and water from the Rurichu stream, producing an additional 40 MW. Together, the plant generates approximately 291 GWh of energy annually.

Chhukha Hydropower Plant: As Bhutan's oldest mega power plant, the Chhukha Hydropower Plant was commissioned in 1986. It has a capacity of 336 MW, with four hydro-turbine units each generating 84 MW. The plant's annual electricity generation exceeds 1,800 GWh, and a significant portion is exported to India.

Dagachhu Hydropower Plant: Commissioned in March 2015, the Dagachhu Hydropower Plant has a capacity of 126 MW. It is a run-of-the-river project located in Dagana and operates under a Public-Private Partnership. The plant generates an estimated average of 515 GWh annually, with all electricity being sold to India.

Kurichhu Hydropower Plant: The Kurichhu Hydropower Plant is a run-of-river scheme located in Gyalpozhing, Monggar. It consists of four units, each with a capacity of 15 MW, resulting in a total installed capacity of 60 MW. The plant generates an average annual energy of 400 GWh using Kaplan turbines. Notably, the project includes a fish ladder to facilitate fish migration.

Mangdechhu Hydropower Plant: Located on the Mangdechhu River in Trongsa, the Mangdechhu Hydropower Plant has a capacity of 720 MW. Construction began in 2012, and the plant became operational in stages from 2019. It is expected to generate 3,008 GWh of electricity annually and help mitigate 2.2 million metric tons of CO_2 emissions per year.

Tala Hydropower Plant: Situated downstream of the Chhukha Hydropower

Plant, the Tala Hydropower Plant is the largest in Bhutan. It has a total capacity of 1,020 MW and commenced operations in 2006. All the electricity generated by the plant is exported to India through transmission lines.

2.1.2. Generation

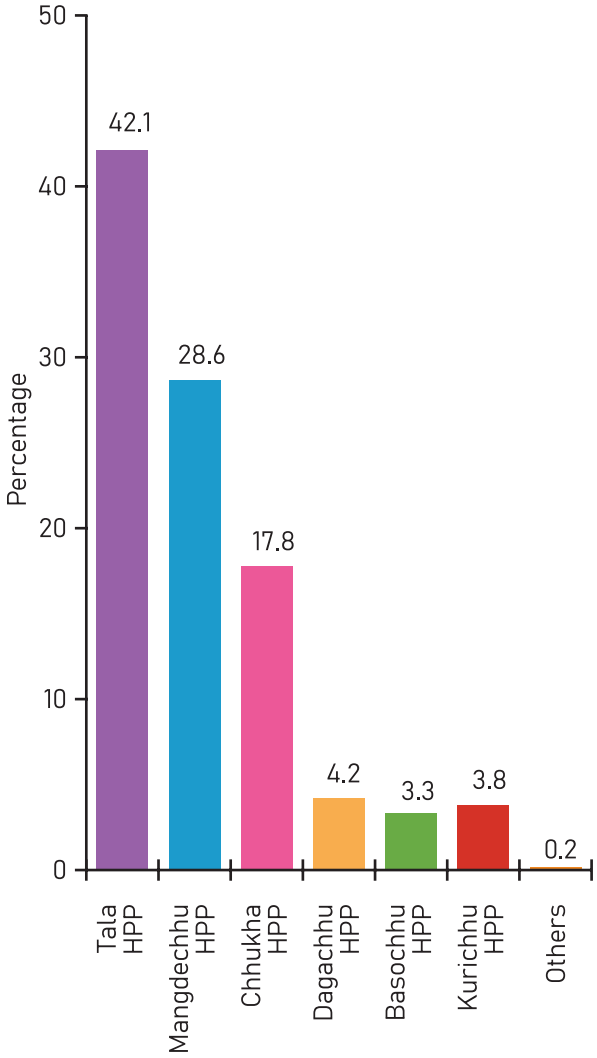
Figure 2.2 provides a comparative visualization of the actual generation proportions among the hydropower plants. In 2022, the Tala Hydropower Plant emerged as the largest contributor, accounting for 42.1 percent of the total electricity generation from hydropower. Following closely behind is the Mangdechhu Hydropower Plant, which contributed 28.6 percent of the total power. Lastly, the Chhukha Hydropower Plant accounted for 17.8 percent of the total power generation in that year.

2.1.3. Exports and Imports

The data reveals an upward trajectory in power exports, indicating a consistent increase over time. Starting at 5,383.2 GWh in 2015, the country's power exports reached a peak of 9,259.7 GWh in 2020. Subsequently, there was a slight decrease to 8,075.5 GWh in 2021, followed by a further decline to 7,240.2 GWh in 2022.

Conversely, the trend in power imports is less definitive. Following a decline from 2015 to 2016, there was a modest increase in 2017, which was followed by a significant jump to 133 GWh in 2018. Since then, power imports had generally shown a decreasing or stable pattern, reaching a low point of 81.8 GWh in 2020. Notably, while power exports experienced a substantial increase in 2020, power imports sharply declined. However, in 2022, power imports rebounded and doubled to 203.9 GWh compared to the previous year (Figure 2.3).

Figure 2.2: Composition of Electricity Generation in 2022 (Percent)



Source: BPC Power Data Book 2022

2.2. Petroleum Products

Bhutan has a long-term agreement with India to import petroleum products, which are distributed by four main companies: Bhutan Oil Distributor, Damchen Petroleum, Druk Petroleum Corporation Limited, and State Trading Corporation of

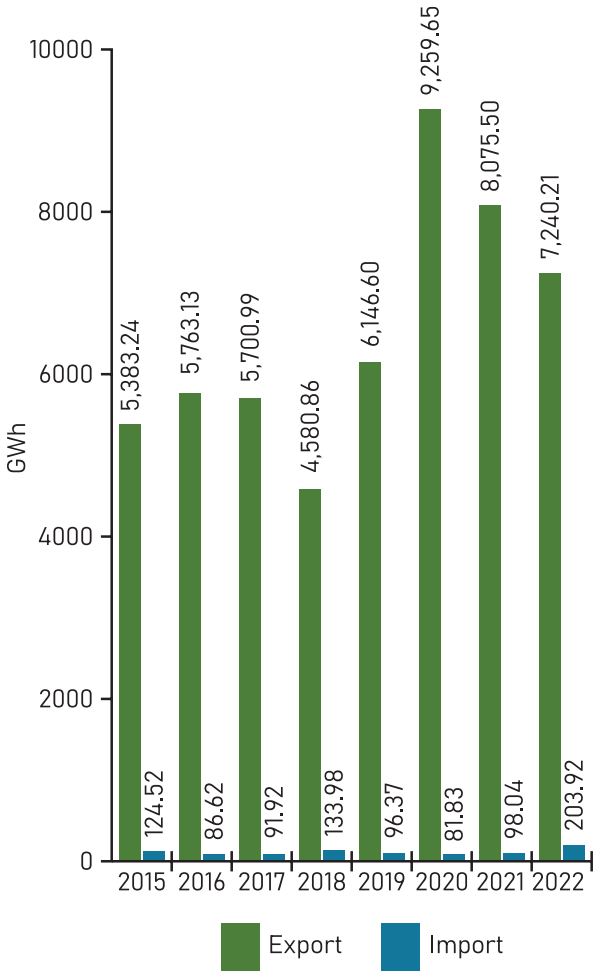
Bhutan Limited. The Department of Trade is responsible for regulating the petroleum market in Bhutan, ensuring a steady supply of these products.

Examining Table 2.1, it is evident that the consumption of LPG initially experienced growth but has witnessed a slight decline in recent years. On the other hand, S.K Oil consumption has consistently decreased over time. Kerosene (ATF) consumption displayed fluctuations, with a notable decrease in 2021. Petrol consumption, although subject to minor variations, has demonstrated an overall increasing trend. Meanwhile, diesel consumption has remained relatively stable, with slight fluctuations observed

2.3. Coal and Derivatives

Based on the data presented in Figure 2.4 for the year 2022, a clear pattern emerged in coal production and imports. Sub-bituminous coal accounted for the highest production volume, reaching 133,501.10 MT. In terms of imports, coke/semi-coke of coal had the highest volume at 108,998.06 MT, followed by sub-bituminous coal at 39,389 MT and other coals at 14,979.08 MT. Notably, sub-

Figure 2.3: Exports and Imports of Electricity from 2016 to 2022 (GWh)



Source: BTS 2015 to 2022

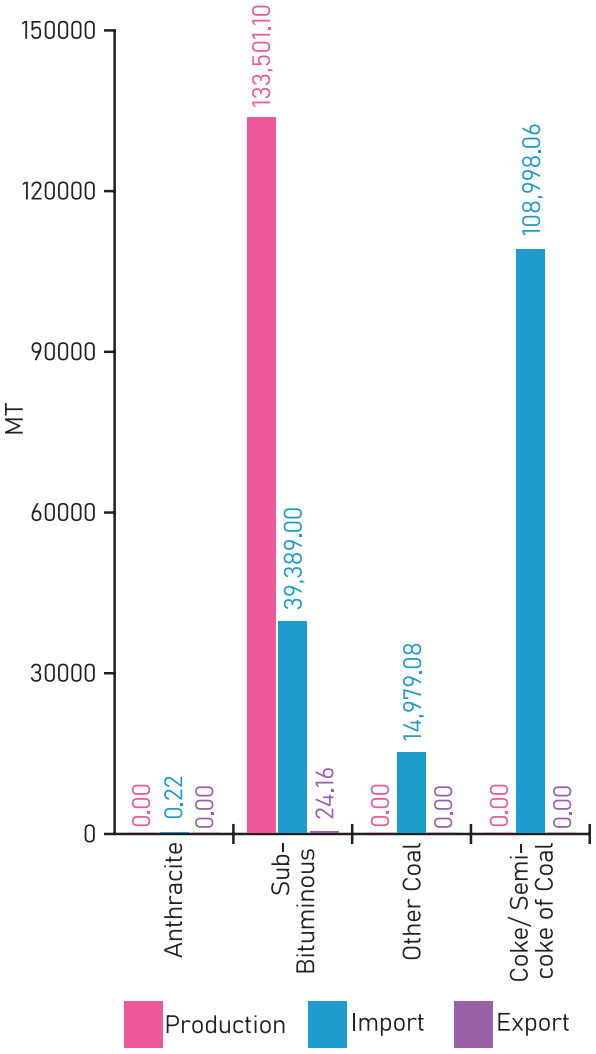
Table 2.1: Import of Petroleum Products from 2018 to 2022

Fuel	Unit	Year				
		2018	2019	2020	2021	2022
LPG	Kg	5,016,953	10,198,148	9,107,690	8,889,640	8,331,665
S.K Oil	kl	3,585	2,922	1,698	1,730	1,144
Kerosene (ATF)	kl	4,878	4,956	1,720	1,239	2,307
Petrol	kl	46,912	50,959	34,776	33,331	36,697
Diesel	kl	159,723	154,617	108,987	113,424	107,643

Source: BTS 2018 to 2022

bituminous coal was the only coal category that saw export activity, with a volume of 24.16 MT.

Figure 2.4: Production, Import, and Export of Different Types of Coal in 2022 (MT)



Source: DGM, BTS 2022

2.4. Biomass

Biomass refers to the renewable organic matter derived from plants and animals. In Bhutan, biomass plays a major role in fulfilling the country's energy requirements. Fuelwood stands out as the primary biomass energy resource used in Bhutan. Particularly in rural areas, wood remains a vital fuel source, primarily used for cooking and heating purposes. Notably, Bhutan maintains an impressive forest cover, accounting for approximately 71 percent of its total land area (2,717,161.64 hectares).

2.4.1. Fuelwood

Fuelwood has historically played a significant role in Bhutan. In urban areas, the supply of fuelwood is generally well accounted for, as it is primarily sourced from the depots of the National Research and Development Corporation Limited (NRDCL). However, in rural areas, accurately estimating the supply of fuelwood is challenging. According to this Study, the estimated fuelwood supply in 2022 amounted to 250,179.22 MT.

2.4.2. Briquettes

Briquettes are a condensed and compacted form of biomass waste that is produced through the application of heat and pressure. In Bhutan, briquettes are primarily produced from waste wood and sawdust obtained from local sawmills. These briquettes serve as an alternative to fuelwood in various heating applications in households and industries. The production of briquettes in 2022 amounted to 132.39 MT, representing a 58 percent reduction as compared to the production of 316.15 MT in 2014.

2.4.3. Biogas

In rural households, fuelwood remains the primary choice for cooking and heating. However, this reliance on fuelwood contributes to deforestation, greenhouse gas emissions, and harmful indoor smoke that affects household health. To address these issues, the promotion of biogas can bring about various benefits. It provides increased

access to modern cooking and heating methods, leading to reduced greenhouse gas emissions and deforestation. Biogas also helps reduce health risks from indoor air pollution caused by firewood smoke. Additionally, it saves time spent collecting firewood and improves crop yields by utilizing organic by-products from biogas plants.

Biogas plants in Bhutan are available in various sizes, ranging from 4 m^3 to 70 m^3. As of December 2022, a total of 8,306 biogas plants have been installed, with an estimated cumulative biogas generation of 6,116.9 MT (Table 2.2).

Table 2.2: Estimated Annual Generation of Biogas in 2022 (MT)

Size (m^3)	Number	Capacity	Generation (MT)
4	4,148	1.2	2,205.6
6	3,733	2	3,308.3
8	415	2.8	514.9
10	0	3.6	0.0
30	3	9.78	13.0
50	3	16.48	21.9
60	1	30	13.3
70	3	30	39.9
Total	8,306		6,116.9

Source: Developed from DoL data

2.5. Other Alternative Renewable Energy Resources

Bhutan places significant emphasis on renewable energy sources to fulfill its primary energy requirements. The country primarily relies on hydropower and biomass, which together form the majority of its energy supply mix. Hydropower stands as the dominant source, but Bhutan also holds untapped potential in other alternative renewable resources. These include solar energy, wind energy, and energy derived from municipal solid waste. Exploring and harnessing these additional sources can further diversify Bhutan's renewable energy portfolio.

2.5.1. Solar Energy

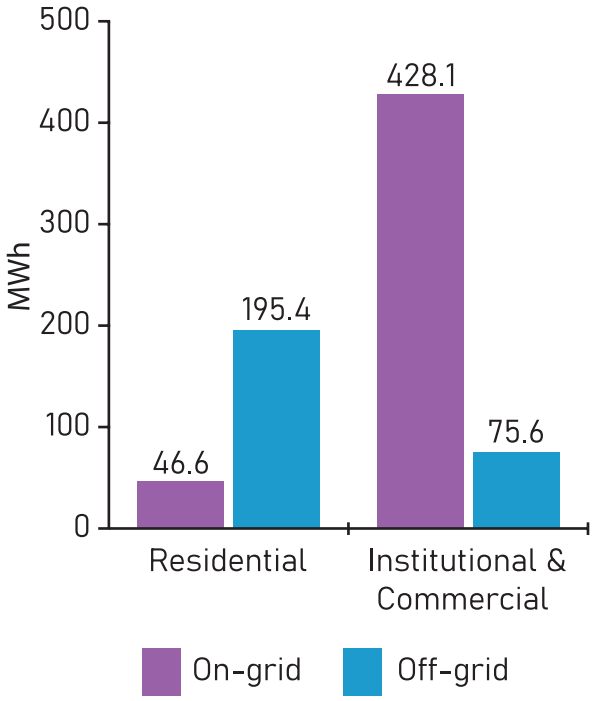
According to the Renewable Energy Resource Assessment 2015, Bhutan has a theoretical potential of 3,706,328 MW for solar photovoltaic power generation based on solar irradiance. However, this assessment also considered various constraints, such as rugged terrain, national protected areas, and other restrictions, resulting in a restricted theoretical development potential of approximately 12,000 MW for solar PV power generation in Bhutan.

In 2022, a total of 745.7 MWh of solar electricity was generated, with the majority originating from institutional and commercial buildings (Table 2.5).

2.5.2. Solar water heating

Heating accounts for a significant portion of energy consumption, particularly in rural areas where the predominant use of fuelwood for heating purposes leads to emissions. A solar water heating system is a device that utilizes solar energy to heat water, catering to a wide range of needs in residential, commercial, and industrial settings. Around 1.67 MWh was generated in 2022 from the various solar water heating systems installed in public institutions, residential areas, and commercial establishments.

Figure 2.5: Solar Electricity Generation in 2022 (MWh)



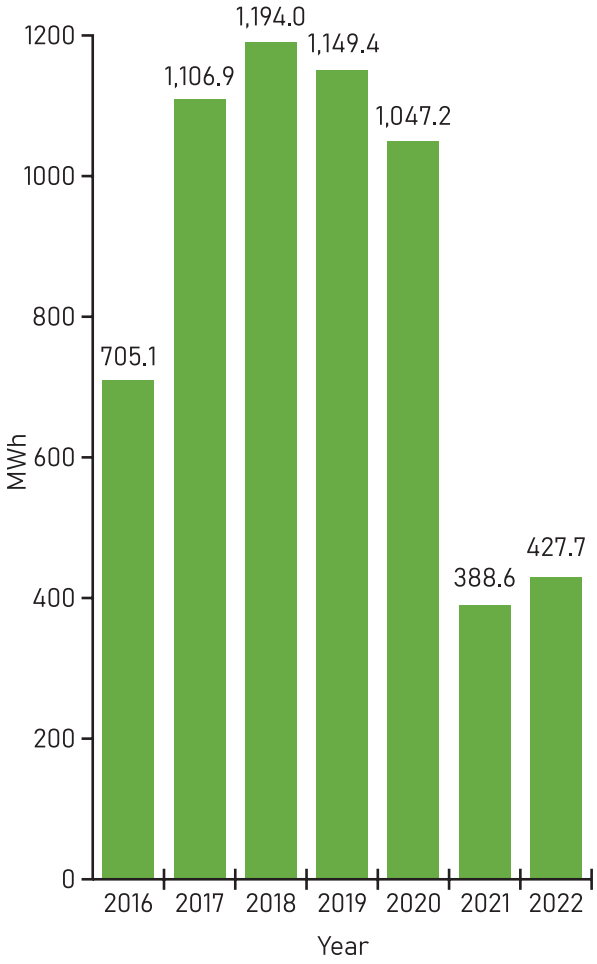
Source: DoE

2.5.3. Wind Energy

Bhutan has substantial capacity for leveraging wind power systems. The restricted theoretical development potential for wind power in the country is estimated to be approximately 761 MW, with Wangdue Phodrang exhibiting the highest potential at 141.7 MW, followed by Chhukha at 91.8 MW (DRE, 2015).

In 2022, Bhutan generated a total of 427.7 MWh of electricity from wind power. Although this marked an increase compared to the previous year, it fell short of the levels achieved in 2016 when the country first started harnessing wind energy (Figure 2.6).

Figure 2.6: Wind Energy Generation from 2016 to 2022 (MWh)



Source: BPC Power Data Book 2022

2.5.4. Waste to Energy Potential

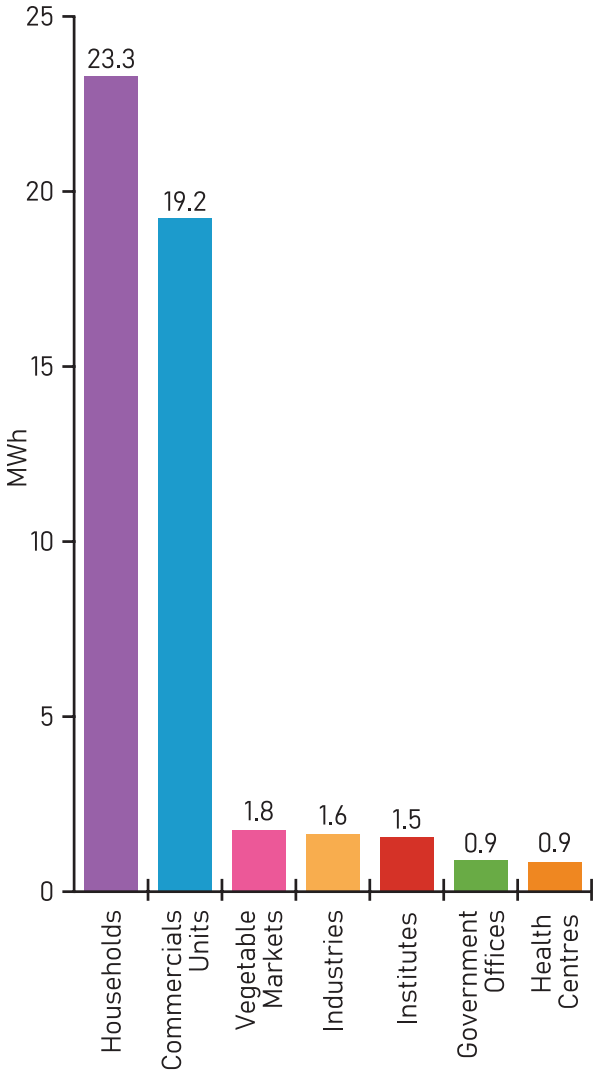
Waste management and environmental conservation hold great importance in Bhutan. According to the National Waste Inventory Survey 2019, the country produces around 172,161 kg of solid waste daily, with each person contributing approximately 0.23 kg. The majority of this waste, over 85 percent, comes from households and commercial units, with food waste being the largest component at 45.9 percent. Plastics, paper, and cardboard also make significant contributions, accounting for 17.1 percent and 15.8 percent, respectively (NSB, 2020).

While landfilling is commonly used for waste disposal, incineration is a costlier alternative. It is crucial to address the management of e-waste, despite its relatively small percentage in the overall waste generated. Implementing effective policies for recycling and managing e-waste is essential.

Among different waste types, glass waste makes up five percent, while e-waste, other waste, and green plants are generated in smaller quantities, each accounting for less than two percent. The substantial proportion of household and commercial waste highlights the significance of implementing efficient waste management strategies, with a particular focus on composting organic waste, which constitutes nearly half of the total waste generated.

As shown in Figure 2.7, the theoretical capacity for producing electricity from waste is projected to reach a maximum of 49.23 MWh per day (equivalent to 17,967 MWh annually). Specifically, household waste alone has the potential to generate approximately 23.3 MWh per day (or 8,506 MWh annually). This renewable energy source has the capability to fulfill a significant portion of the energy requirements for households and businesses, thereby reducing reliance on conventional energy sources

Figure 2.7: Theoretical Potential of Waste to Energy Generation Per Day in 2019 (MWh)



Source: Developed from National Waste Inventory Survey 2019 data

2.5.5. Green hydrogen

Green hydrogen is widely recognized as a clean and sustainable energy source with immense potential to facilitate the critical transition towards a low-carbon future. Unlike other types of hydrogen, green hydrogen is produced through the process of electrolysis, employing renewable energy sources such as solar and wind power to split water molecules. As the global community intensifies efforts to mitigate greenhouse gas

emissions and confront the challenges posed by climate change, the advent of green hydrogen represents a highly promising solution that can effectively decarbonize various sectors including transportation, industry, and power generation.

The versatility of green hydrogen enables its application across a wide range of sectors, making it a compelling solution for multiple purposes. It can serve as a fuel for locomotives, provide heating for buildings, facilitate industrial processes such as fertilizer production, act as an energy storage medium, and contribute to electric power generation. Given the extensive opportunities that hydrogen presents, countries worldwide have committed substantial investments to ensure the establishment of a secure, robust, and resilient energy system. Furthermore, these investments aim to significantly reduce carbon emissions by substituting fossil fuels in "hard-to-abate" sectors of the economy.

Currently the DoE is actively engaged in preparing a green hydrogen roadmap. This roadmap will serve as a blueprint outlining the planned initiatives, targets, and milestones for the development and utilization of green hydrogen within the country.

CHAPTER

03

ENERGY DEMAND

This chapter examines the energy consumption characteristics of the high-energy sectors, categorized broadly as Building, Industry, and Transport. The Building Sector is divided into residential and commercial and institutional segments. Electricity has become the primary energy source in Bhutan, with the Building Sector shifting from fuel-wood to electricity. Industries consume the most electricity, followed by residential households. Other fuels such as diesel and LPG are also used in the Building and Industry sectors for heating and cooking. The Transport Sector primarily relies on petrol and diesel, but with the increasing use of electric vehicles, it is expected to shift towards electricity as the primary fuel.

Bhutan is rapidly shifting towards electricity and other renewable sources of energy due to government policies, technological advancements, and increasing public awareness of the need for sustainable development.

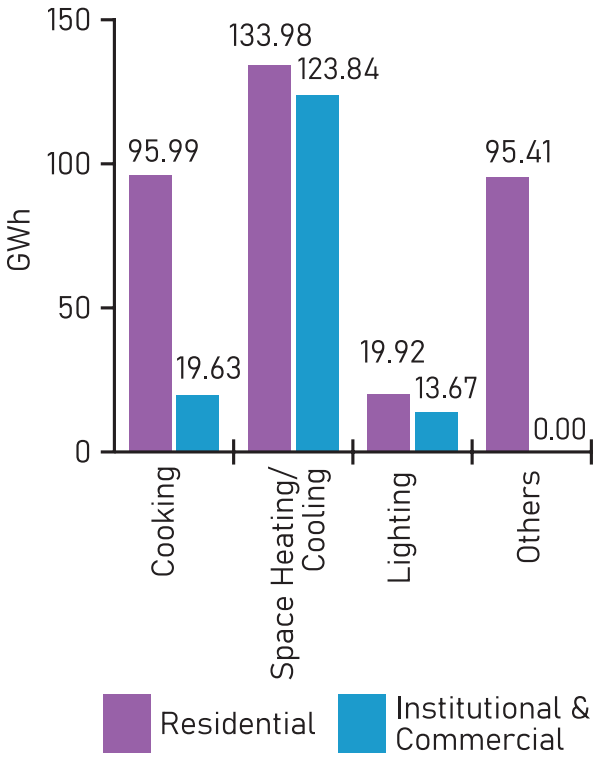
3.1. Building Sector

3.1.1 Electricity

The peak demand had reached 540.44 MW in 2022 as compared to 435.35 MW in 2021. During the year 2022, BPC serviced 232,465 customers, an increase of 4.7 percent from the previous year (BPC, 2023).

The Building Sector in Bhutan consumed a total of 502.44 GWh of electricity in 2022, accounting for 14.5 percent of the country's total electricity consumption (3,465.95 GWh). As shown in Figure 3.1, within the Building Sector, residential buildings accounted for the majority of electricity consumption, representing 345.29 GWh or 68.7 percent of the total electricity consumed in the sector. Commercial and institutional buildings made up the remaining 157.14 GWh (or 31.3%). In terms of the source of electricity, hydro comprised the largest share at 95.9 percent while embedded hydro comprised 3.9 percent. In contrast, solar and wind contributed just 0.2 percent.

Figure 3.1: Electricity Consumption in the Building Sector (GWh)



Source: BPC Power Data Book 2022, Energy Survey for Building Sector 2022, and Energy

Space heating/cooling consumed the largest amount of electricity in the residential segment, accounting for 38.8 percent (133.95 GWh) of the total residential consumption, followed by cooking at 27.8 percent (95.99 GWh). Others (which includes pumps, washing

machines, refrigerators, and televisions) accounted for 27.6 percent (95.41 GWh), while lighting had the lowest consumption at 5.8 percent (19.92 GWh). High electricity consumption in space heating/cooling, cooking, and 'others' indicates that implementing energy efficiency measures could significantly reduce overall electricity consumption.

Space heating/cooling is by far the largest consumer of electricity in the institutional/commercial segment, accounting for 78.9 percent (123.50 GWh) of total electricity consumption. This is over six times the electricity consumption for cooking (19.63 GWh or 12.5%). Lighting had the lowest consumption accounting for just under 13.56 GWh or 8.7 percent of total electricity consumption for this segment.

Further analysis shows that electricity consumption has increased steadily over the years, with a compound annual growth rate (CAGR) of 5.9 percent from 2014 to 2022. The residential segment has exhibited faster growth than the institutional sector, with CAGRs ranging from 1.9 to 12.4 percent over this period. It suggests an increasing demand for housing and the rise of residential energy consumption. Meanwhile, the institutional/commercial segment has shown moderate growth, with CAGRs ranging from 2.7 percent to 10.3 percent.

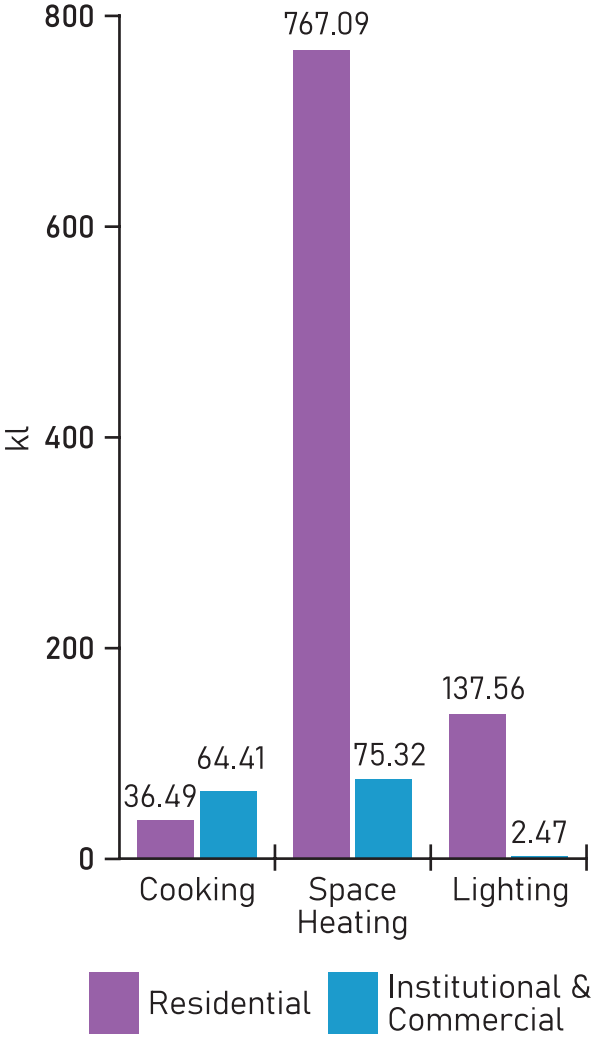
3.1.2. Kerosene

Kerosene consumption in the Building Sector was 1,091.18 kl, which represents 95.8 percent of the total consumption (1,139.56 kl). It can be inferred that kerosene is still widely used as an energy source for various purposes, particularly in the Building Sector, despite the availability of other alternatives. The residential segment of the Building Sector consumed a total of 948.98 kl of kerosene, accounting for 87 percent of the sectoral energy consumption with heating being the most significant contributor. This suggests that households in the residential segment may not have access to more efficient and cleaner energy sources for heating purposes or prefer using kerosene-based heating equipment.

As shown in Figure 3.2, the breakdown of the residential segment's kerosene consumption is as follows: cooking - 36.49 kl (3.85 %); heating - 767.09 kl (80.8%); and lighting - 137.56 kl (14.5%).

The institutional and commercial segment still relies on kerosene for cooking and heating. This segment consumed a total of 142.20 kl of kerosene, accounting for 13 percent of the sectoral energy consumption. The breakdown of the institutional and commercial segment's kerosene consumption is as follows: cooking - 64.41 kl (45.3%), heating - 75.32 kl (52.9%) and lighting - 2.47 kl (1.7%).

Figure 3.2: Kerosene Consumption in the Building Sector (kl)



Source: Energy Survey for Building Sector 2022

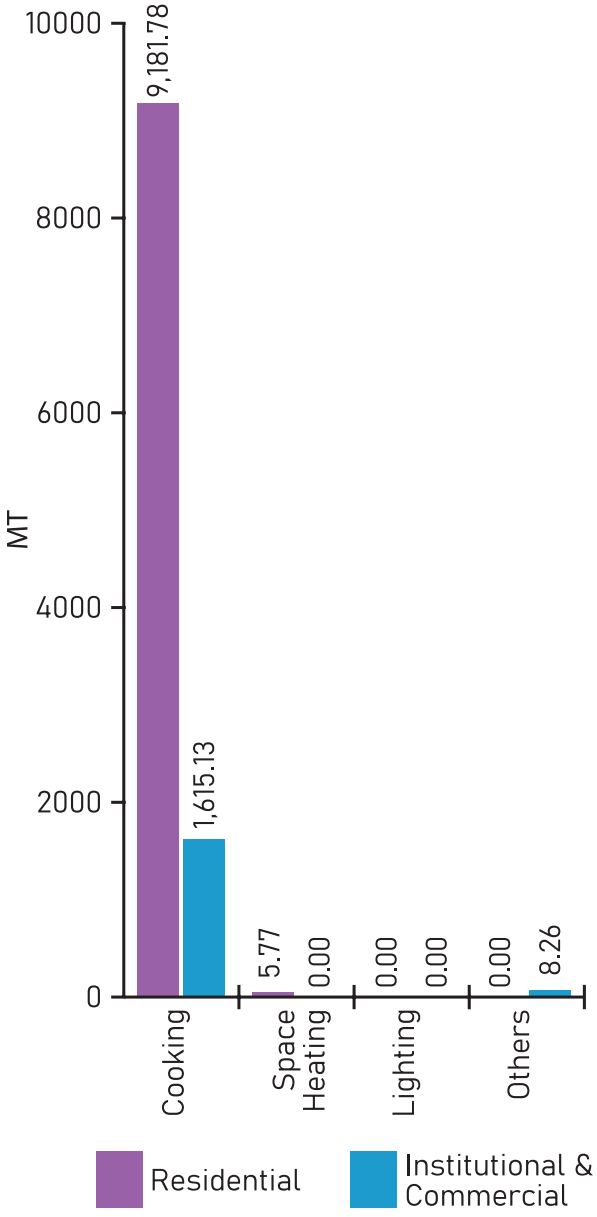
3.1.3. Diesel

The total diesel consumption among the different sectors, including Building, Industry, Transport, and others, is 102,708.21 kl. Among these sectors, the Building Sector had the lowest diesel consumption at 83.58 kl. This is mainly due to the fact that diesel generators were primarily used for backup power in the institutional and commercial segment of the Building Sector which are not often used due to improved grid stability.

3.1.4. Liquified Petroleum Gas

The Building Sector had a significant demand for LPG, with the residential segment being the biggest consumer. The total LPG consumption for 2022 was 10,810.94 MT, which was entirely consumed by the Building Sector. LPG was primarily used for cooking purposes in both residential, and institutional and commercial segments, with a small portion being used for heating and other purposes.

Figure 3.3: LPG Consumption in the Building Sector (MT)



Source: Energy Survey for Building Sector 2022

As shown in Figure 3.3, the residential segment consumed the majority of LPG at 9,187.55 MT, accounting for about 85 percent of the total consumption. Within the residential segment, LPG was primarily used for cooking purposes, with a consumption of 9,181.78 MT (99.9%). The remaining (0.06%) was used for heating purposes.

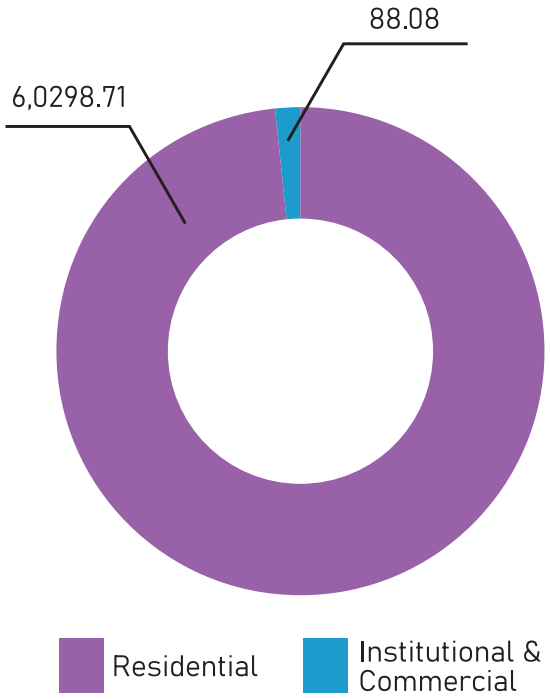
The institutional and commercial segment consumed 1,623.39 MT of LPG, which is 15 percent of the total consumption. LPG was primarily used for cooking purposes in this segment, accounting for 99.5 percent (1,615.13 MT) of the total consumed by this segment. The remaining 0.5 percent (8.26 MT) was used for other purposes.

3.1.5. Biomass

3.1.5.1. Bio-gas

Bio-gas was produced by 8,296 domestic bio-gas plants and 10 commercial plants. The total consumption of bio-gas for 2022 was 6,116.86 MT, with the entire demand fulfilled by the Building Sector. The residential segment consumed the majority of bio-gas at 6,028.78 MT, which is equivalent to 98.6 percent of the total consumption and it was solely used for cooking purposes. The institutional and commercial segment consumed only 88.08 MT of bio-gas, which accounts for only 1.4 percent of the total consumption (Figure 3.4).

Figure 3.4: Bio-gas (including WTE) Consumption in the Building Sector (MT)



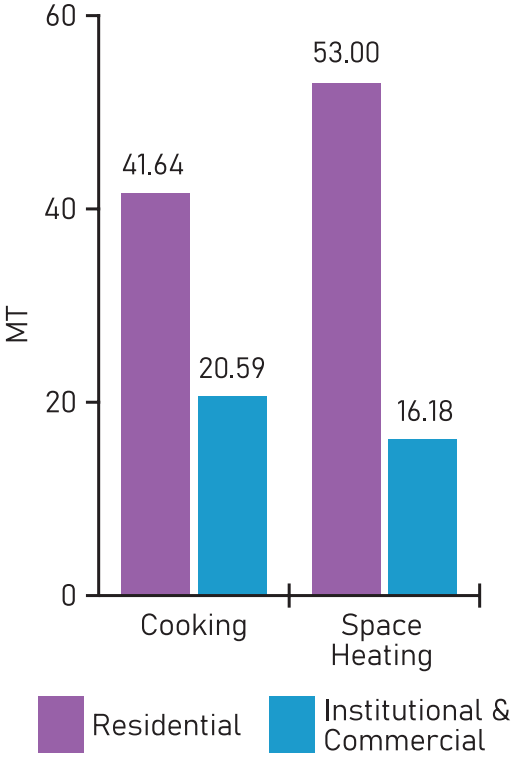
Source: DoE and DoL, 2022

3.1.5.2. Briquettes

The Building Sector was the sole consumer of 132.39 MT of briquettes for the year 2022. The residential segment consumed the majority of briquettes at 94.64 MT, accounting for 71.5 percent of the total consumption. Out of this, 44 percent of the briquettes were used for cooking, while 56 percent were used for heating purposes.

The institutional and commercial segment consumed 37.75 MT of briquettes, which is 28.51 percent of the total consumption. Within this segment, 56 percent of briquettes were used for cooking purposes, while 44 percent were used for heating purposes (Figure 3.5).

Figure 3.5: Briquettes Consumption in the Building Sector (MT)



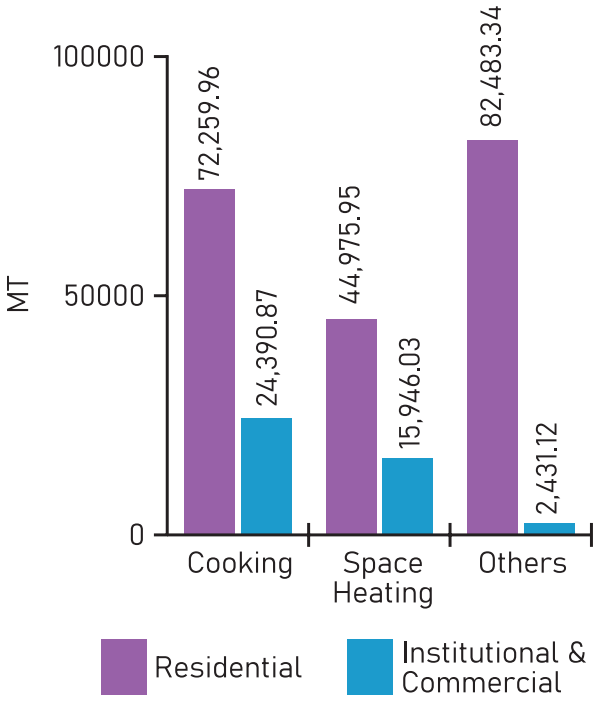
Source: Energy Survey for Building Sector 2022

3.1.5.2. Fuel Wood

The fuelwood consumption for the year 2022 was 254,601.27 MT and the Building Sector had the highest demand for fuelwood at 242,487.27 MT (95.2%).

As presented by Figure 3.6, within the Building Sector, the residential segment consumed the majority of fuelwood at 199,719.25 MT, accounting for 82.4 percent of the total consumption. Cooking was the main purpose of fuelwood use in this segment (36.2%), followed by other purposes, which included annual rituals, hot stone baths, and art and crafts (41.3%), and heating (22.5%). The institutional and commercial segment consumed 42,768.02 MT of fuelwood. Within this segment, cooking was also the primary purpose of fuelwood use (57.0%), followed by heating (37.3%), and other purposes (5.7%).

Figure 3.6: Fuelwood Consumption in the Building Sector (MT)



Source: Energy Survey for Building Sector 2022

3.2. Industry Sector

The Industry Sector is a crucial component of Bhutan's economy. According to the National Statistics Bureau's National Accounts Report 2022, the Industry Sector contributed around 34.2 percent to Bhutan's GDP in 2021, making it the second-largest sector after the Service Sector, highlighting the importance of the Industry Sector in sustaining Bhutan's economic growth. However, there is scope for improvement, especially in increasing energy efficiency of large and medium-scale industries, which can lead to cost savings and reduced environmental impact.

CSIs are an important segment, contributing significantly to employment. While not energy-intensive, there is room for improving this segment's energy efficiency and environmental impact. The

number of CSIs has grown by 35.5% since 2014 though there was a 3.6% decline in 2020-2021 due to the COVID-19 pandemic. Despite challenges, CSIs generated over 90,000 jobs in 2020-2021 as compared to 41,764 in 2014. Focus on energy efficiency and sustainability is crucial for the Sector's long-term development.

Bhutan's competitive edge lies in the relatively low electricity tariffs, which can be attractive for businesses looking to operate in the country. The major industry clusters are located in Pasakha, Phuentshogling, Gomtu, and Pugli. While a few major manufacturing firms dominate the Sector, many smaller businesses are engaged in handicrafts, food processing, construction, wood, saw-mills, poly-products, and paper processing. Overall, the Industry Sector in Bhutan is vital to the country's economic growth, and both large and small businesses play an important role. Optimizing energy consumption and promoting competitiveness in the Sector should be a priority for the government and businesses alike.

Electricity is the primary fuel input in Bhutan's Industry Sector, with the ferro-alloys, steel, and cement-based industries as the major consumers. In contrast, other industries such as sawmills, briquetting, packaging, poly-products, wire, and marble account for less than 0.5 percent of the total electricity consumption (i.e., 6.6 GWh per year). Thermal energy consumption in the Industry is dominated by coal, which is a vital input for many industries in Bhutan. However, liquid fuels such as diesel, kerosene oil, and furnace oil account for less than 6 percent of the industry's thermal energy mix. Among liquid fuels, fuel oils are primarily used in the food and beverage industries, while coal is used mainly in the cement and ferro-alloy industries.

Despite the continuous increase in coal consumption, there has been a significant reduction in fuelwood consumption in the Industry Sector. This change could be mainly due to the substitution of fuelwood by electricity for heating purposes. Additionally, there has been a shift towards using light diesel oil (LDO) and high-speed diesel, reducing the Industry's dependence on industrial superior kerosene oil (SKO). These changes not only reduce the Industry's dependence on traditional fuels but also improve energy efficiency and reduce greenhouse gas emissions.

As shown in Table 3.1, the fuel consumption trends in the Industry Sector have varied between 2014 to 2022, with significant increases in electricity and kerosene consumption, stable biomass consumption, and decreases in LPG and coal consumption. Diesel consumption has moderately increased, emphasizing its continued importance as a fuel source in the Industry Sector.

Electricity and kerosene consumptions in the Industrial Sector have seen significant increases at Compound Annual Growth Rates (CAGR) of 7.6 percent and 11.0 percent respectively, indicating a notable shift towards these fuels. However, biomass consumption, particularly

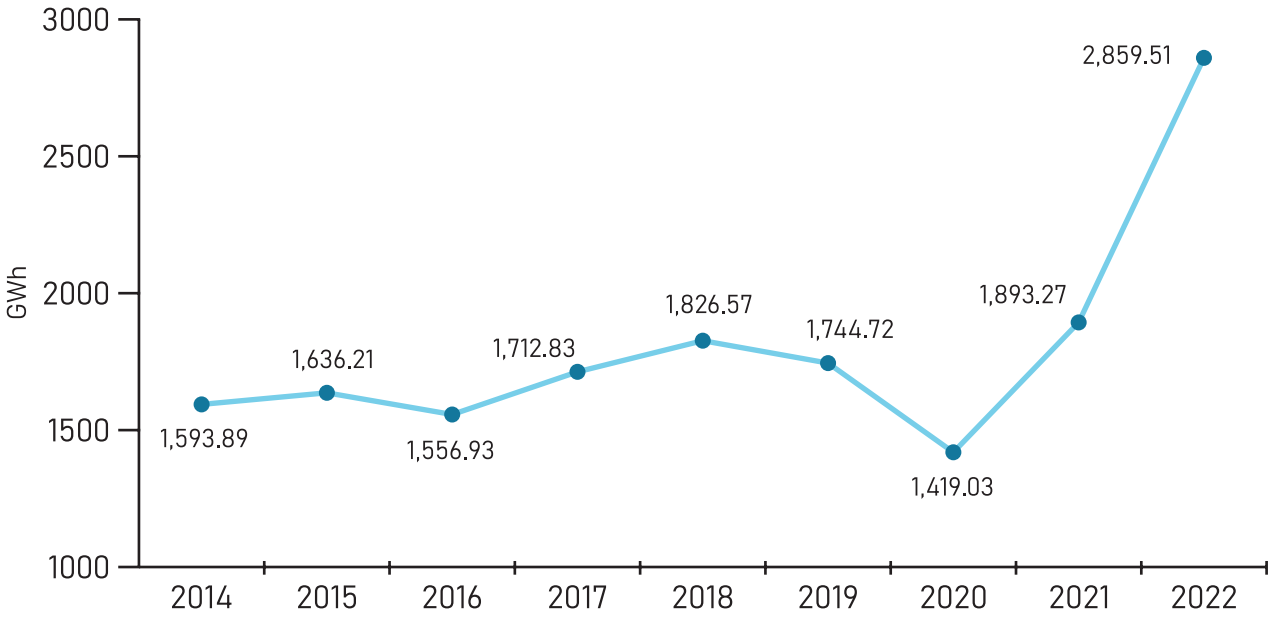
fuelwood, has only experienced slight growth with a CAGR of 0.72 percent, suggesting a slower progress despite its potential as a sustainable energy source. Several factors, including the availability and affordability of alternative energy sources, along with environmental concerns, may contribute to this sluggish growth. LPG consumption declined in 2022 with a CAGR of 1.6 percent. Diesel consumption displayed significant growth at a CAGR of 5.9 percent, highlighting its continued importance as a fuel in the Industry Sector.

3.2.1. Electricity

Figure 3.7 shows that electricity consumption in the Industry Sector has been fluctuating over the years, with some years experiencing a decrease in consumption while others see an increase.

The recorded CAGR for electricity consumption between 2014 and 2022 was 7.58 percent, signaling a consistent and steady increase in electricity usage over the past nine years. This relatively high growth rate implies a rapid surge in the demand for electricity within the country.

Figure 3.7: Electricity Consumption in the Industry Sector from 2014 to 2022



Source: BPC Power Data Book 2022

Table 3.1: Energy Consumption in the Industry Sector in 2014 and 2022

Fuel	Unit	2014	2022	CAGR
Electricity	GWh	1,593.9	2,859.5	7.6%
Kerosene	kl	21.0	48.4	11.0%
Biomass (Fuelwood)	MT	11,439.2	12,114.0	0.7%
Liquefied Petroleum Gas	MT	516.6	456.0	-1.6%
Diesel	kl	2,787.9	4,394.2	5.9%

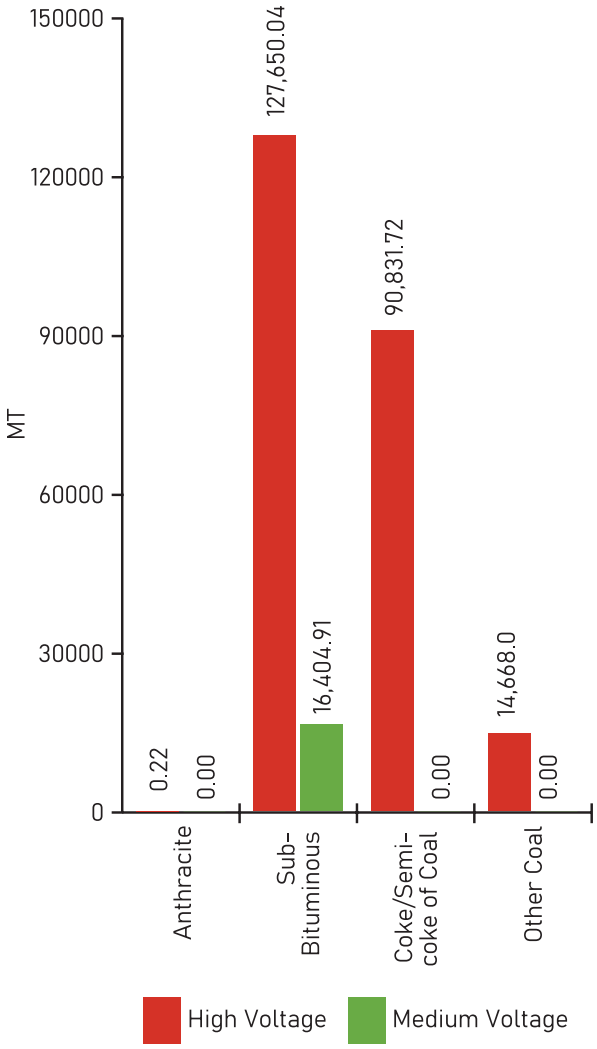
Source: Energy Survey for Industry Sector 2022

Total electricity consumed in the Industry Sector was 2,859.51 GWh in 2022, with a majority of it going to HV industries at 2,621.39 GWh, representing 91.7 percent of the share. The MV industries consumed 221.38 GWh (7.7%) while the LV and CSI industries combined consumed 8.71 GWh and 8.03 GWh, respectively, representing a combined share of a mere 0.6 percent. The data highlights the considerable disparity in electricity consumption between different industry types, with HV industries consuming the majority of electricity.

3.2.2. Coal and derivatives

As illustrated in Figure 3.8, the HV Industry Sector was the main driver of demand for anthracite coal in Bhutan, with a total consumption of 0.22 MT. Also, the HV industry emerged as the primary consumer of sub-bituminous coal, with a total demand of 127,650.04 MT, making up 88.6 percent of the total demand. Regarding Coke/Semi-coke of Coal, the HV sector became the sole consumer with a total demand of 90,831.7 MT. There was no demand from the MV and LV industries.

Figure 3.8: Consumption of Coal and Derivatives in 2022 (MT)

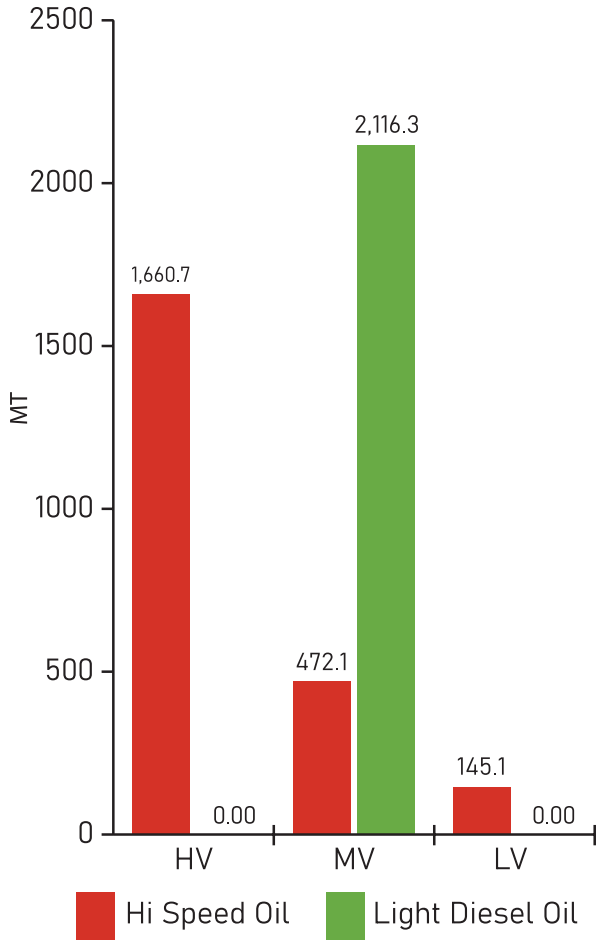


Source: Energy Survey for Industry Sector 2022

3.2.3. Diesel

The total diesel consumption in 2022 was recorded at 4,394.2 kl as compared to 1,606 kl in 2014, with a CAGR of 5.8 percent. In 2022, all demand for light diesel oil was from MV industries and none from HV, LV or CSI. However, the demand for high-speed diesel oil was reported from HV at 1,660.67 kl, MV at 472.1 kl, and the remaining from LV at 145.1 kl (Figure 3.9).

Figure 3.9: Consumption of Diesel by Type of Industries



Source: Energy Survey for Industry Sector 2022

3.2.5. Other fuels

Apart from electricity, coal and derivatives, and diesel, the Industry Sector also made use of additional fuel sources, including furnace oil, fuel wood, and charcoal. The industries reported utilizing 955.75 kl of furnace oil. Moreover, fuel wood consumption witnessed a 6 percent increase, rising from 11,439.2 MT in 2014 to 12,114 MT in 2022. Additionally, industries consumed approximately 119,898 MT of charcoal in the same year.

3.3 Transport Sector

The Transport Sector is an essential component of infrastructure that facilitates the movement of people, goods, and services. In Bhutan, road and air transport services dominate due to the absence of alternative modes of transport. However, this heavy reliance on these modes of transport has significant implications for energy consumption and environmental sustainability, as almost all the energy used in the Sector is derived from imported fossil fuels. To address this issue, it may be worth exploring alternative, sustainable sources of energy, promoting sustainable modes of transport, and improving the efficiency of existing infrastructure to balance the need for efficient transport systems with environmental sustain-ability and energy security. Bhutan exports up to 80 percent of the electricity it produces every year. However, the majority of the revenue generated from these electricity exports is spent on the importation of fuel from India, specifically to meet the energy needs of Bhutan's Transport Sector. The cost of importing petrol and diesel has been increasing over the years until 2018, and it drastically dropped in 2020 and steadily increased since then to Nu 11,491 million in 2022.

As shown in Figure 3.10, the number of vehicles has been increasing over the years, 75,190 in 2014 to 125,534 in 2022. The total value of imports of petroleum products in Bhutan for the year 2022 was Nu 14,263 million (NSB, 2014) of which petrol and diesel contributed to around 82 percent.

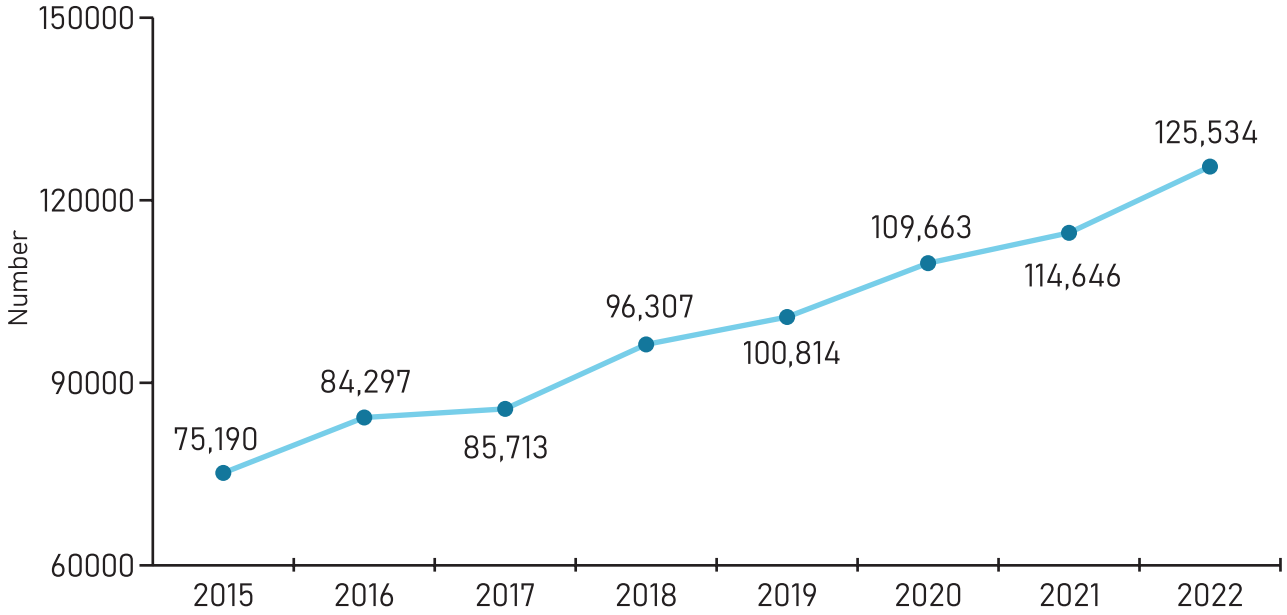
The energy needs of the Transport Sector were primarily met by diesel, petrol, and

ATF. Specifically, in the aviation segment, a total of 2,122.21 kl of ATF was consumed in 2022. Looking at the road transport sector, the government has initiated the adoption of electric and hybrid-electric vehicles to introduce electricity as an alternative energy source. By December 2022, there were 471 registered electric vehicles in the country (BCTA, 2022). To encourage the shift from fossil fuel-based transportation to cleaner options, the government has implemented tax exemptions on electric vehicles.

at 41.1 percent. Medium vehicles consumed only 5 percent of the total diesel, while tractors accounted for the least diesel consumption at 0.6 percent.

In contrast, petrol was mainly consumed by light vehicles or taxis, making up 92.4 percent of the total consumption. The remaining 7.6 percent of petrol consumption was by two-wheelers.

Figure 3.10: Number of Vehicles from 2015 to 2022

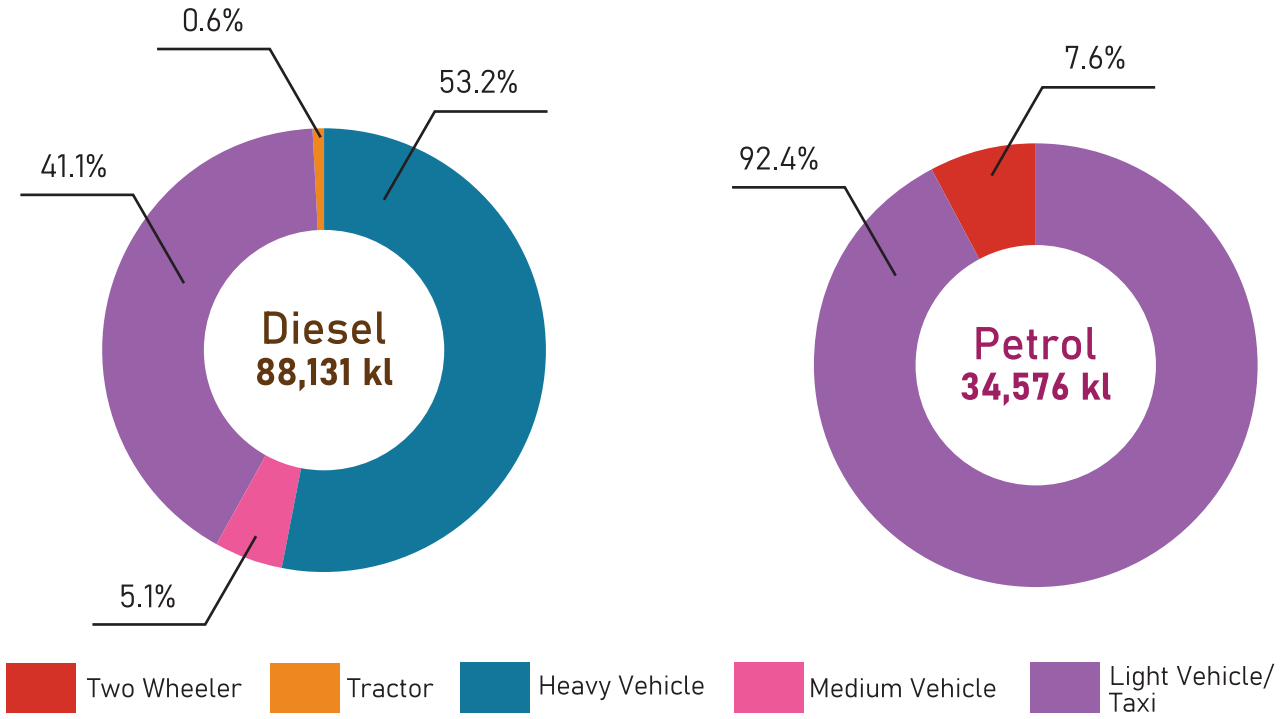


Source: MoIC 2022

The data presented in Figure 3.11 indicates a significant difference in the consumption of diesel and petrol in vehicles[1]. Diesel consumption is approximately 2.5 times higher than petrol consumption. Among diesel-consuming vehicles, heavy vehicles represent the largest proportion, accounting for 53.2 percent of the total consumption, followed by light vehicles

[1] The vehicles that are not used for *'transport'* are excluded. These included heavy earth moving equipment and power tillers.

Figure 3.11: Petrol and Diesel Consumption by Type of Vehicles in 2022



Source: Energy Survey for Transport Sector 2022

CHAPTER

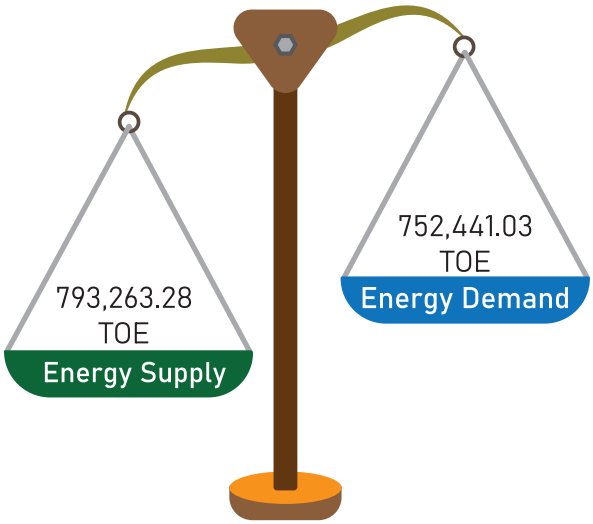
04

ENERGY BALANCE AND FUEL MIX

4.1. Overview of Energy Supply and Demand

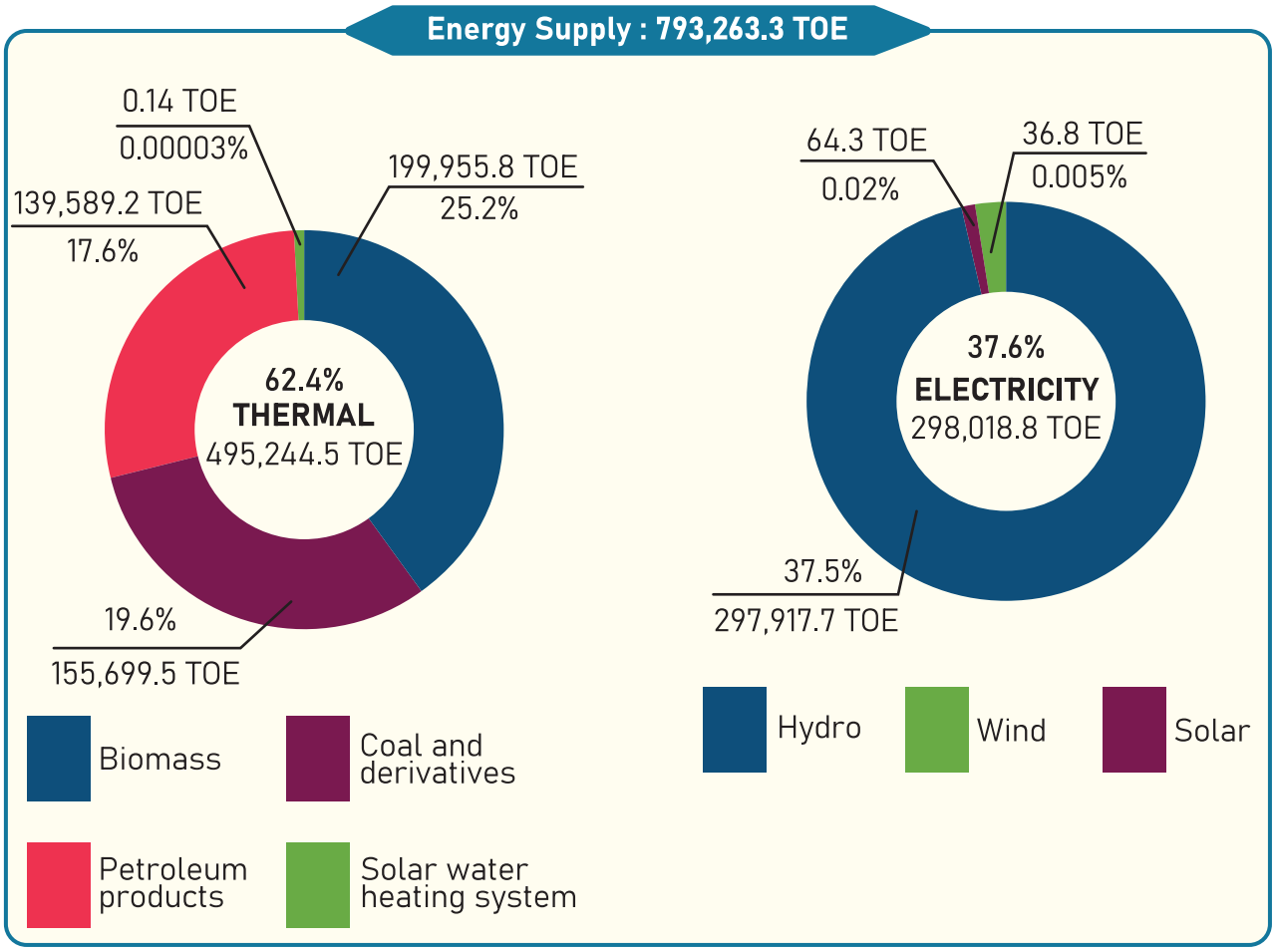
In 2022, the total energy supply of the country was 793,263.28 TOE, against a total energy demand of 752,441.03 TOE. The country's energy supply in 2022 exceeded its energy demand by 40,822.25 TOE (Figure 4.1). The total energy supply in 2022 saw a significant increase from 2014's 650,220 TOE, corresponding to a CAGR of 2.52 percent. Similarly, the total energy consumption increased from 2014's 650,220 TOE, representing a CAGR of 1.84 percent.

Figure 4.1: Total Energy Supply and Demand in 2022 (TOE)



Losses/ Stocks/ Statistical discrepancies: 40,822.25 TOE

Figure 4.2: Energy Supply in 2022 (TOE)



4.2. Energy Supply

In 2022, the total energy supply of the country recorded 739,263.28 TOE. Thermal energy sources, which include coal and its derivatives, biomass, and petroleum products, constituted a significant portion of the energy mix, making up 62.4 percent (495,244.5 TOE) of the total energy supply; the remaining 37.6 percent (298,018.5 TOE) was attributed to electricity.

In terms of the energy mix, electricity constituted the largest portion of the total TOE, followed closely by biomass at 25.2 percent (199,955.8 TOE), coal and its derivatives at 19.6 percent (155,699.5 TOE), and petroleum products at 17.6 percent (139,589.2 TOE) (Figure 4.2). However, electricity from alternative renewable sources like solar and wind contributed less than 1 percent combined (Figure 4.2).

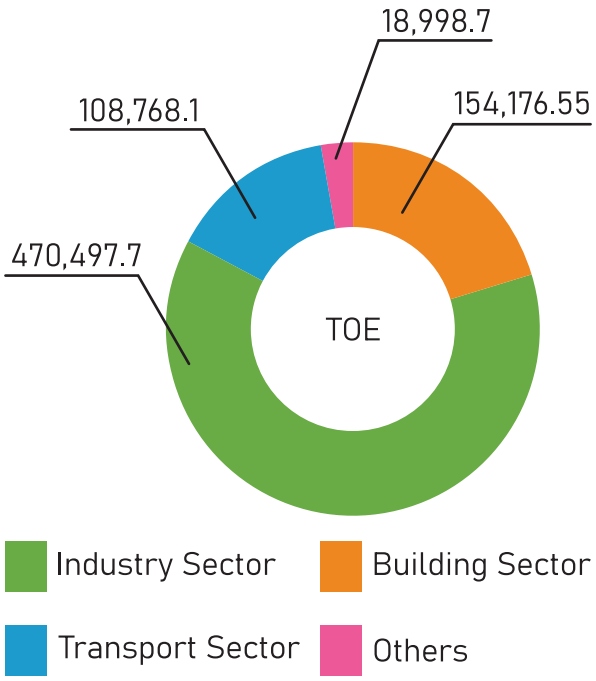
4.3. Energy Demand

The country's total energy consumption in 2022 was 752,441.03 TOE. The Industry Sector is the largest consumer of energy, while the Building and Transport Sectors also consume significantly. Other sectors account for a smaller portion. The Building Sector accounted for 154,176.55 TOE, making up 20.5 percent of the total energy consumption. The Industry Sector consumed the largest share at 470,497.7 TOE, representing 62.5 percent of the total. The Transport Sector followed with 108,768.1 TOE, accounting for 14.5 percent of the total energy consumption. The remaining energy consumption, totaling 18,998.7 TOE or 2.5 percent of the total, was attributed to various other sectors (Figure 4.3).

Thermal energy dominated as the primary source of energy consumption, making up 60.4 percent, while the remaining portion was attributed to electricity. Looking at thermal energy, of the total petroleum consumption, diesel was the most consumed petroleum product at 91,727.4 TOE, representing 66.8 percent of the total consumed. Comparatively, petrol was consumed at a much lower level, with 29,250.1 TOE consumed, accounting for only 21.3 percent of total consumption. LPG had a consumption level of 12,728.3 TOE, representing 9.3 percent of the total consumption. This is notably higher than kerosene, which had the lowest consumption among petroleum products, with a consumption level of 2,782.56 TOE, representing only 3.03 percent of total consumption. Furnace oil was reported to be the least consumed product, with a consumption of only 819.8 TOE, which constituted a mere 0.6 percent of the total consumption amount. This was the lowest consumption among all the petroleum products.

Coal and its derivatives contributed to 130,370.7 TOE. On the other hand, petroleum products was responsible for 137,307.1 TOE. Additionally, biomass consumed 186,744.6 TOE.

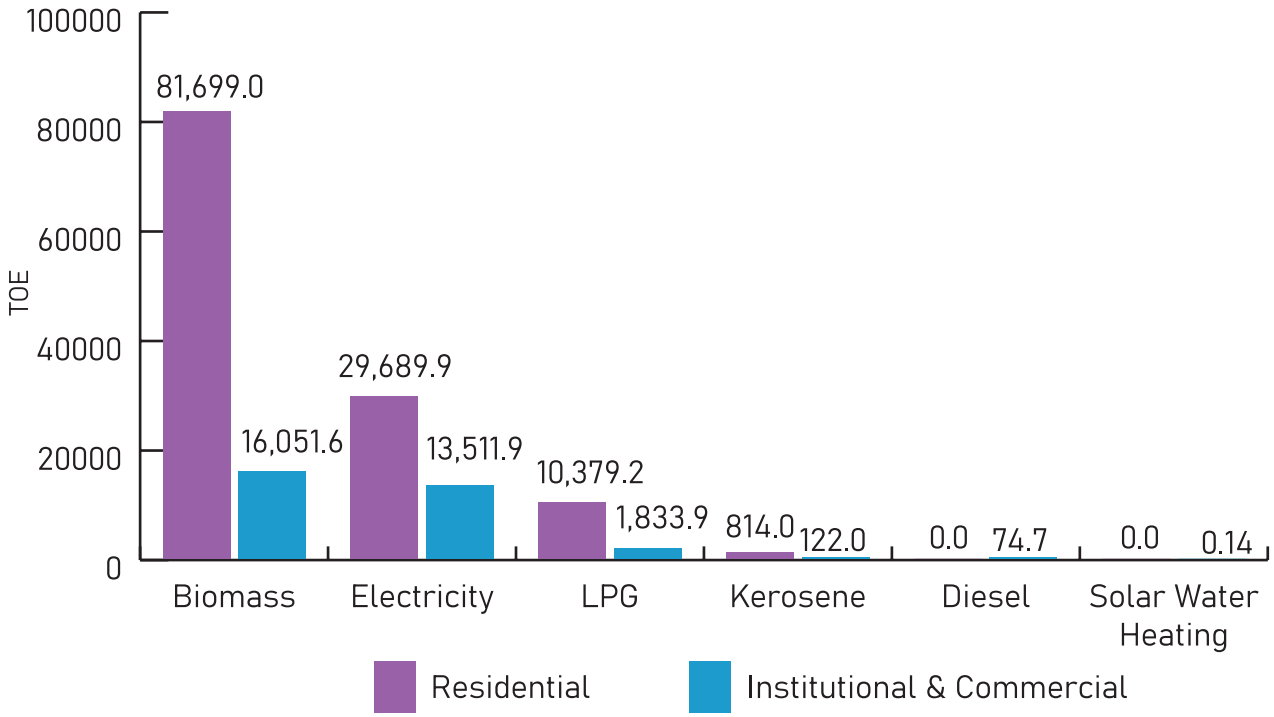
Figure 4.3: Energy Demand by Different Sectors in 2022 (TOE)



4.3.1. Building Sector

The total fuel consumption in the Building Sector was 154,176.55 TOE, with biomass being the most consumed fuel at 97,750.5 TOE, accounting for 63.4 percent of the total fuel consumed. Electricity was the second most consumed fuel at 43,201.8 TOE, representing 28.0 percent of total fuel consumption. LPG was the third most consumed fuel at 12,213.1 TOE, accounting for 7.9 percent of total fuel consumption, and kerosene was the second least consumed fuel at only 936.0 TOE, representing 0.6 percent of the total fuel consumed. Diesel was the least consumed fuel for this Sector. Cooking was the end-use with the highest consumption for all fuels, accounting for about half of the total consumption at 42.5 percent or 65,511.6 TOE, followed by space heating/cooling at 29.6 percent or 45,616.3 TOE. Likewise, among the four fuels – electricity, kerosene, LPG, and biomass – the majority of the energy were consumed by the residential segment as compared to the institutional and commercial segment (Figure 4.4).

Figure 4.4: Energy Consumption Mix in the Building Sector in 2022 (TOE)



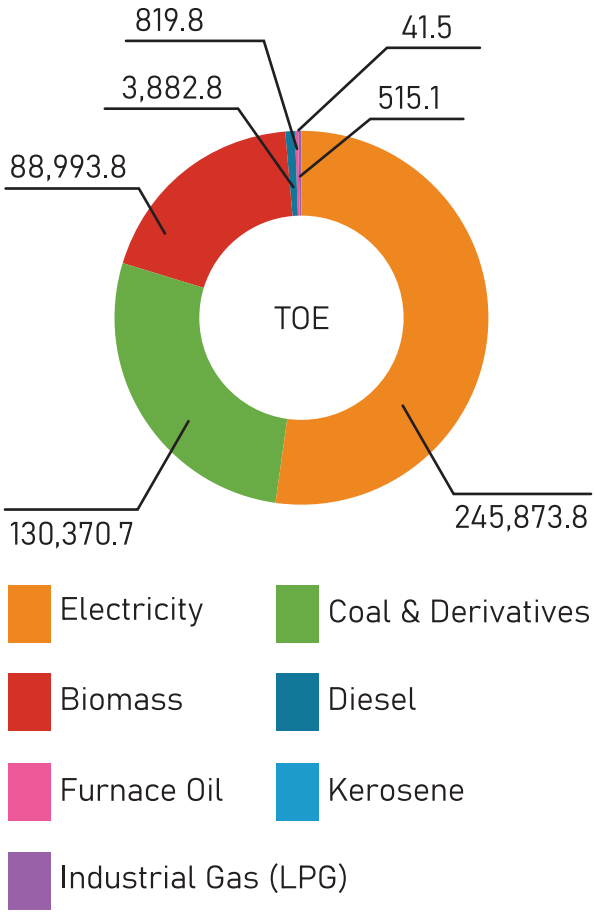
In the institutional and commercial segment, the fuel consumption at 31,594.1 TOE was significantly lower than the residential segment. Biomass was the most consumed fuel at 16,051.6 TOE, accounting for 50.8 percent of total fuel consumption, followed by electricity at 13,511.9 TOE, accounting for 83.9 percent of total fuel consumption. LPG at 1,833.9 TOE represented 5.8 percent of total fuel consumption. Kerosene and diesel were the least consumed fuels with only 122.0 (0.4%) TOE and 74.7 (0.2%) TOE, respectively. Space heating (43.1%) accounted for the highest consumption of all end-uses in the institutional and commercial segment, with electricity being the most consumed fuel.

4.3.2. Industry Sector

Figure 4.5 illustrates that electricity was the largest source of fuel consumption, accounting for 52.3 percent (245,873.8 TOE) in 2022. Coal & derivatives was the second largest source of fuel consumption, accounting for 27.7 percent (130,370.74 TOE). Biomass consumption was 18.9 percent (88,993.81 TOE) in 2022. This increase is partly due to the inclusion of charcoal in the biomass category in 2022, which alone contributed to 84,480.13 TOE. This suggests that biomass has significant potential as a source of energy in the future. Kerosene, diesel and industrial gas (LPG) had relatively small shares and furnace oil accounted for 0.2 percent of the total fuel consumed for this sector.

Figure 4.6 shows that HV dominates the Industry Sector's energy consumption, followed by MV, LV, and the CSI sector, with each subsequent level having progressively smaller energy consumption shares. The Industry Sector's energy consumption was primarily dominated by the HV, accounting for a significant 93.3 percent of the total energy consumption. This corresponds to an energy consumption of 439,053.61 TOE.

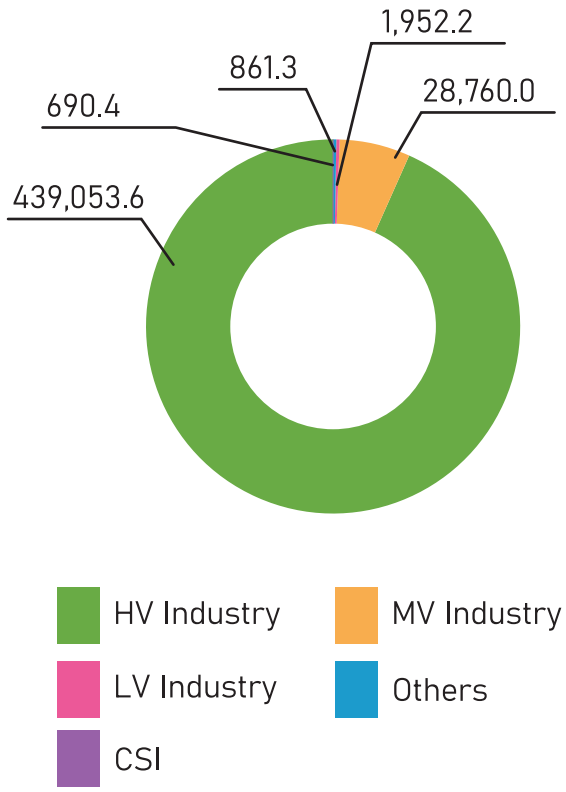
Figure 4.5: Energy Consumption Mix in the Industry Sector in 2022 (TOE)



In comparison, the medium voltage level consumed a considerably smaller portion, representing about 6.1 percent of the total energy consumption, equivalent to 28,760.01 TOE. The LV in the Industry Sector had a relatively minor share, utilizing around 0.4 percent of the total energy consumption, totaling 1,952.19 TOE. Lastly, the CSI sector, consumed the smallest fraction, contributing only 0.1

percent of the total energy consumption, with an energy usage of 690.37 TOE

Figure 4.6: Energy Consumption in the Industry Sector by Type of Industries in 2022 (TOE)



4.3.3. Transport Sector

Road transport exhibited significantly higher energy demands as compared to aviation, largely due to the greater energy requirements associated with land-based vehicles. Aviation consumed a total of 1,805.04 TOE, primarily from kerosene. In contrast, road transport had a much higher energy consumption of 106,963.10 TOE. While aviation relied solely on kerosene as its energy source, road transport utilized a combination of electricity, diesel, and petrol. Notably, road transport derived 49.01 TOE of energy from electricity, which was not used in aviation. Diesel was the primary energy source for road transport, accounting for 78,745.37 TOE, followed by petrol at 28,168.71 TOE (Table 4.1).

4.4. Future Scenario of Fuel Mix

Analysing the current fuel mix in the country and its projected trend until 2046 provides valuable insights into the nation's fuel dependency and allows for meaningful comparisons (Figure 5.1). Based on the observed patterns in the economy over the past decade, it is evident that electricity will continue to dominate, contributing to approximately 67.7 percent of the overall fuel mix by 2046. This is followed by diesel (9.8%), petrol (8.5%), coal (6.6%), biomass (5.2%), and LPG (1.2%). Notably, biomass, which currently holds the largest share in the fuel mix, is expected to decline at a CAGR of 4 percent (Figure 4.7).

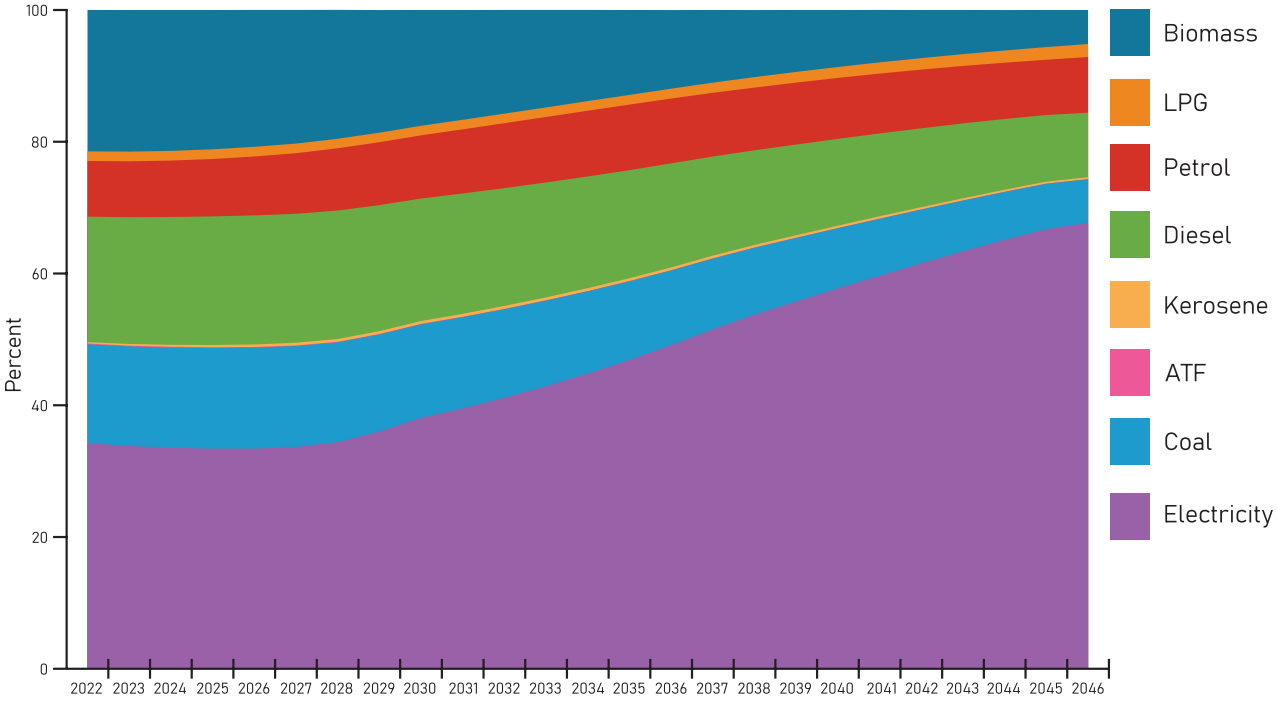
The Figure further indicates that electricity, coal, and diesel will maintain their dominance over biomass in the future, aligning with the ongoing fuel usage trends. As the country operates multiple coal mines, the usage of coal is expected to increase. However, there is also potential for coal consumption to be

Table 4.1: Energy Mix in the Transport Sector in 2022 (TOE)

Transport	Electricity	Kerosene	Diesel	Petrol	Total
Aviation		1,805.04			1,805.04
Road	49.01		78,745.37	28,168.71	106,963.14
Total	49.01	1,805.04	78,745.37	28,168.71	108,768.14

largely substituted by electricity, considering the high accessibility of electricity. This shift is supported by the expectation of electricity becoming a more cost-effective option compared to the scarcity and limited availability of high-grade coal.

Figure 4.7: Future Scenario of Fuel Mix-Business as Usual Scenario, upto 2046 (Percent)



ENERGY BALANCE IN ORIGINAL UNITS (2022)

Major sources of energy consumed in the economy and their classification >>>>			Coal & Derivatives				Electricity					
			Anthracite	Sub-Bituminous	Other Coal	Coke/ Semi-coke of Coal	Hydro	Embedded Hydro		Solar		Wind
							On Grid	On Grid	Off Grid	On Grid	Off Grid	On Grid
Unit >>>>			Tonnes	Tonnes	Tonnes	Tonnes	GWh	GWh	GWh	GWh	GWh	GWh
Energy Supply	Generation/Production		-	133,501.10	-	-	10,679.20	18.86	0.51	0.47	0.27	0.43
	Imports		0.22	39,389.00	14,979.08	108,998.06	203.92	-	-	-	-	-
	Exports		-	24.16	-	-	7,240.21	-	-	-	-	-
	Total Primary Supply		**0.22**	**172,865.94**	**14,979.08**	**108,998.06**	**3,642.91**	**18.86**	**0.51**	**0.47**	**0.27**	**0.43**
	Secondary Generation/Transfer		-	-	-	-	-	-	-	-	-	-
	Aggregate Supply		0.22	172,865.94	14,979.08	108,998.06	3,445.41	18.86	0.51	0.47	0.27	0.43

Major sources of energy consumed in the economy and their classification >>>>			Coal				Electricity					
			Anthracite	Sub-Bitu-minous	Other Coal	Coke/ Semi-coke of Coal	Hydro	Embedded Hydro		Solar		Wind
							On Grid	On Grid	Off Grid	On Grid	Off Grid	On Grid
Unit >>>>			Tonnes	Tonnes	Tonnes	Tonnes	GWh	GWh	GWh	GWh	GWh	GWh
Energy Consumption	Total Consumption (Aggregate Demand)		0.22	144,055.95	14,668.00	90,831.72	3,445.41	18.86	0.51	0.47	0.27	0.43
	Building Sector	Sectoral Energy Consumption (Building Sector)	-	-	-	-	481.89	18.86	0.51	0.47	0.27	0.43
		Residential Segment: Residential Segment Total	-	-	-	-	331.44	12.97	0.35	0.05	0.20	0.29
		Residential Segment: Cooking	-	-	-	-	92.19	3.61	0.10	0.01	-	0.08
		Residential Segment: Space Heating/Cooling	-	-	-	-	128.67	5.04	0.14	0.02	-	0.11
		Residential Segment: Lighting	-	-	-	-	18.94	0.74	0.02	0.00	-	0.02
		Residential Segment: Others	-	-	-	-	91.63	3.59	0.10	0.01	-	0.08
		Institutional & Commercial Segment: Institutional & Commercial Segment Total	-	-	-	-	150.46	5.89	0.16	0.43	0.08	0.13
		Institutional & Commercial Segment: Cooking	-	-	-	-	18.80	0.74	0.02	0.05	-	0.02
		Institutional & Commercial Segment: Space Heating/Cooling	-	-	-	-	118.63	4.64	0.13	0.34	-	0.11
		Institutional & Commercial Segment: Lighting	-	-	-	-	13.02	0.51	0.01	0.04	-	0.01
		Institutional & Commercial Segment: Others	-	-	-	-	-	-	-	-	-	-
	Industry Sector Industry Sector	Sectoral Energy Consumption (Industry Sector)	0.22	144,054.95	14,668.00	90,831.72	2,859.51	-	-	-	-	-
		High Voltage	0.22	127,650.04	14,668.00	90,831.72	2,621.39	-	-	-	-	-
		Medium Voltage	-	16,404.91	-	-	221.38	-	-	-	-	-
		Low Voltage	-	-	-	-	8.71	-	-	-	-	-
		CSI	-	-	-	-	8.03	-	-	-	-	-
	Transport Sector	Sectoral Energy Consumption (Transport Sector)	-	-	-	-	0.57	-	-	-	-	-
		Aviation	-	-	-	-	-	-	-	-	-	-
		Road	-	-	-	-	0.57	-	-	-	-	-
	Other Sectors		-	-	-	-	103.43	-	-	-	-	-
	Losses/Stocks/Statistical discrepancies		-	28,810.99	311.08	18,166.34	197.50		-			

ENERGY BALANCE IN ORIGINAL UNITS (2022)

Solar Water heating	Kerosene		Diesel		Petrol	Liquified Petroleum Gas		Furnace Oil	Biomass			
	Aviation Turbine Fuel	SKO	Hi Speed Oil	Light Diesel Oil	Motor Spirt	LPG	Industrial Gas	Furnace Oil	Bio-gas (Including WTE)	Briquettes	Fuelwood	Charcoal
GWh	Kilolitre	Kilolitre	Kilolitre	Kilolitre	Kilolitre	Tonnes	Tonnes	Kilolitre	Tonnes	Tonnes	Tonnes	Tonnes
0.002	-	-	-	-	-	-	-	-	6,116.86	132.39	250,179.22	
-	2,307.47	1,144.16	106,104.45	1,538.67	36,696.73	7,783.34	548.31	1,385.98	-	-	-	140,986.36
-	-	-	-	-		-	-	-	-	-	-	-
0.002	**2,307.47**	**1,144.16**	**106,104.45**	**1,538.67**	**36,696.73**	7,783.34	548.31	1,385.98	6,116.86	132.39	250,179.22	140,986.36
-	-	-	-	-	-	-	-	-	-	-	-	-
0.002	2,307.47	1,144.16	106,104.45	1,538.67	36,696.73	7,783.34	548.31	1,385.98	6,116.86	132.39	250,179.22	140,986.36

Solar Water heating	Kerosene		Diesel		Petrol	Liquified Petroleum Gas		Furnace Oil	Biomass			
	Avaiation Turbine Fuel	SKO	Hi Speed Oil	Light Diesel Oil	Motor Spirt	LPG	Industrial Gas	Furnace Oil	Bio-gas (Including WTE)	Briquettes	Fuelwood	Charcoal
GWh	Kilolitre	Kilolitre	Kilolitre	Kilolitre	Kilolitre	Tonnes	Tonnes	Kilolitre	Tonnes	Tonnes	Tonnes	Tonnes
0.002	2,122.21	1,139.56	100,591.89	2,116.32	35,902.88	10,810.94	456.00	955.75	6,116.86	132.39	254,601.27	119,898.00
0.002	-	1,091.18	83.58	-	-	10,810.94	-	-	6,116.86	132.39	242,487.27	-
-	-	948.98	-	-	-	9,187.55	-	-	6,028.78	94.64	199,719.25	-
-	-	36.49	-	-	-	9,181.78	-	-	6,028.78	41.64	72,259.96	-
-	-	767.09	-	-	-	5.77	-	-	-	53.00	44,975.95	-
-	-	137.56	-	-	-	-	-	-	-	-	-	-
-	-	7.86	-	-	-	-	-	-	-	-	82,483.34	-
0.002	-	142.20	83.58	-	-	1,623.39	-	-	88.08	37.75	42,768.02	-
-	-	64.41	-	-	-	1,615.13	-	-	-	21.14	24,390.87	-
-	-	75.32	-	-	-	-	-	-	-	16.61	15,946.03	-
	-	2.47	-	-	-	-	-	-	-	-	-	-
0.002	-	-	-	-	-	8.26	-	-	-	-	2,431.12	-
-	-	48.38	2,277.86	2,116.32	-	-	456.00	955.75	-	-	12,114.00	119,898.00
-	-	-	1,660.67	-	-	-	187.00		-	-	12,114.00	119,898.00
-	-	-	472.05	2,116.32	-	-	44.00	0.33	-	-	-	-
-	-	-	145.14	-	-	-	225.00	955.42	-	-	-	-
-	-	-	-	-	-	-	-		-	-	-	-
-	2,122.21	-	88,131.36	-	34,575.57	-	-	-	-	-	-	-
-	2,122.21	-	-	-	-	-	-		-	-	-	-
-	-	-	88,131.36	-	34,575.57	-	-		-	-	-	-
-	-	-	10,099.09	-	1,327.31	-	-	-	-	-	-	-
	185.26	4.60	5,512.56	-577.65	793.84	-3,027.60	92.31	430.23	-	-	-4,422.05	21,088.36

ENERGY BALANCE IN TONNES OF OIL EQUIVALENT (2022)

Major sources of energy consumed in the economy and their classification>>>>			Coal & Derivatives				Electricity					
			Anthracite	Sub-Bituminous	Other Coal	Coke/ Semi Coke of Coal	Hydro	Embedded Hydro		Solar		Wind
								On Grid	Off Grid	On Grid	Off Grid	On Grid
Unit >>>>			TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE
Energy Supply	Generation/Production		-	60,262.40	-	-	918,245.67	1,621.90	43.85	40.82	23.30	36.78
	Imports		0.14	17,780.19	4,257.45	73,410.19	17,533.96	-	-	-	-	-
	Exports		-	10.91	-	-	622,545.84	-	-	-	-	-
	Total Primary Supply		**0.14**	**78,031.68**	**4,257.45**	**73,410.19**	**313,233.79**	**1,621.90**	**43.85**	**40.82**	**23.30**	**36.78**
	Secondary Generation/Transfer		-	-	-	-	-	-	-	-	-	-
	Aggregate Supply		0.14	78,031.68	4,257.45	73,410.19	296,251.98	1,621.90	43.85	40.82	23.30	36.78

Major sources of energy consumed in the economy and their classification >>>>			Coal & Derivatives				Electricity					
			Anthracite	Sub-Bitu-minous	Other Coal	Coke/ Semi Coke of Coal	Hydro	Embedded Hydro		Solar		Wind
								On Grid	Off Grid	On Grid	Off Grid	On Grid
Unit >>>>			TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE
Energy Consumption	Total Consumption (Aggregate Demaand)		0.14	65,026.40	4,169.04	61,175.16	296,251.98	1,621.90	43.85	40.82	23.30	36.78
	Building Sector	Sectoral Energy Consumption (Building Sector)	-	-	-	-	41,435.37	1,621.90	43.85	40.82	23.30	36.78
		Residential Segment: Residential Segment Total	-	-	-	-	28,498.28	1,115.35	30.16	4.01	16.80	25.30
		Residential Segment: Cooking	-	-	-	-	7,926.70	310.23	8.39	1.11		7.04
		Residential Segment: Space Heating/Cooling	-	-	-	-	11,063.73	433.00	11.71	1.56		9.82
		Residential Segment: Lighting	-	-	-	-	1,628.90	63.75	1.72	0.23		1.45
		Residential Segment: Others	-	-	-	-	7,878.95	308.36	8.34	1.11		6.99
		Institutional & Commercial Segment: Institutional & Commercial Segment Total	-	-	-	-	12,937.09	506.32	13.69	36.81	6.50	11.48
		Institutional & Commercial Segment: Cooking	-	-	-	-	1,616.64	63.27	1.71	4.60		1.44
		Institutional & Commercial Segment: Space Heating/Cooling	-	-	-	-	10,200.57	399.22	10.80	29.02		9.05
		Institutional & Commercial Segment: Lighting	-	-	-	-	1,119.88	43.83	1.19	3.19		0.99
		Institutional & Commercial Segment: Others	-	-	-	-	-	-	-	-		
	Industry Sector	Sectoral Energy Consumption (Industry Sector)	0.14	65,026.40	4,169.04	61,175.16	245,873.84	-	-	-	-	-
		High Voltage	0.14	57,621.23	4,169.04	61,175.16	225,399.17	-	-	-		
		Medium Voltage	-	7,405.18	-	-	19,035.53	-	-	-		
		Low Voltage	-	-	-	-	748.77	-	-	-		
		CSI	-	-	-	-	690.37	-	-	-		
	Transport Sector	Sectoral Energy Consumption (Transport Sector)	-	-	-	-	49.01	-	-	-	-	-
		Aviation	-	-	-	-	-	-	-	-		
		Road	-	-	-	-	49.01	-	-	-		
	Other Sectors		-	-	-	-	8,893.76	-	-	-	-	-
	Losses/Stocks/Statistical discrepancies		**-**	**13,005.28**	**88.42**	**12,235.03**	**0.00**	**0.23**	**-**	**-**	**-**	**-**

ENERGY BALANCE IN TONNES OF OIL EQUIVALENT (2022)												
Solar Water heating	Kerosene		Diesel		Petrol	Liquefied Petroleum Gas		Furnace Oil	Biomass			
	Aviation Turbine Fuel	SKO	Hi Speed Oil	Light Diesel Oil	Motor Spirit	LPG (Quota)	Industrial Gas	Furnace Oil	Bio-gas (Including WTE)	Briquettes	Fuelwood	Charcoal
TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE
0.14	-	-	-	-	-	-	-		7,363.37	36.69	93,216.78	
	1,962.61	981.46	94,804.33	1,343.26	29,896.82	8,792.84	619.42	1,188.89	-	-	-	99,338.992
	-	-	-	-	-	-	-		-	-	-	
0.14	**1,962.61**	**981.46**	**94,804.33**	**1,343.26**	**29,896.82**	8,792.84	619.42	1,188.89	7,363.37	36.69	93,216.78	99,338.99
	-	-	-	-	-	-	-	-	-	-	-	
0.14	1,962.61	981.46	94,804.33	1,343.26	29,896.82	8,792.84	619.42	1,188.89	7,363.37	36.69	93,216.78	99,338.99

Solar Water heating	Kerosene		Diesel		Petrol	Liquefied Petroleum Gas		Furnace Oil	Biomass			
	Aviation Turbine Fuel	SKO	Hi Speed Oil	Light Diesel Oil	Motor Spirit	LPG (Quota)	Industrial Gas	Furnace Oil	Bio-gas	Briquettes	Fuelwood	Charcoal
TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE	TOE
0.14	1,805.04	977.51	89,878.85	1,847.55	29,250.08	12,213.12	515.14	819.84	7,363.37	36.69	94,864.43	84,480.13
0.14	-	936.02	74.68	-	-	12,213.12	-		7,363.37	36.69	90,350.76	-
-	-	814.04	-	-	-	10,379.17	-		7,257.34	26.22	74,415.39	-
-	-	31.3	-	-	-	10,372.65	-		7,257.34	11.54	26,924.06	-
-	-	658.0	-	-	-	6.52	-		-	14.69	16,758.04	-
-	-	118.0	-	-	-	-	-		-	-	-	-
-	-	6.74	-	-	-	-	-		-	-	30,733.29	-
0.14	-	121.98	74.68	-	-	1,833.94	-	-	106.03	10.46	15,935.36	-
-	-	55.3	-	-	-	1,824.61	-		-	5.86	9,088.04	-
-	-	64.6	-	-	-	-	-		-	4.60	5,941.49	-
-	-	2.1	-	-	-	-	-		-	-	-	-
-	-	-	-	-	-	9.33	-		-	-	905.84	-
-	-	41.50	2,035.27	1,847.55	-	-	515.14	819.84	-	-	4,513.68	84,480.13
-	-	-	1,483.8	-	-	-	211.25		-	-	4,513.68	84,480.13
-	-	-	421.8	1,847.55	-	-	49.71	0.28	-	-	-	-
-	-	-	129.7	-	-	-	254.18	819.56	-	-	-	-
-	-	`	-	-	-	-	-		-	-	-	-
	1,805.04	-	78,745.37	-	28,168.71	-	-	-	-	-	-	-
-	1,805.04	-	-	-	-	-	-		-	-	-	-
-	-	-	78745.37	-	28,168.71	-	-		-	-	-	-
		-	9,023.5	-	1,081.36	-	-	-	-	-	-	-
-	**157.16**	**3.95**	**4,925.47**	**-504.29**	**646.74**	**-3,420.28**	**104.28**	**369.05**	**-**	**-**	**-1,647.66**	**14,858.86**

CHAPTER

05

CONCLUSION

Bhutan's economy was significantly impacted by the COVID-19 pandemic, resulting in a contraction of 10.01 percent in 2020. However, there was a positive turnaround with a growth of 4.09 percent in 2021, indicating signs of recovery. Despite the challenging circumstances, energy consumption in the country reached 752,441.03 TOE in 2022, with the Industrial Sector emerging as the largest consumer, followed by the Building and Transport Sectors. This points to a growing demand for energy resources driven by factors such as population growth, industrial expansion, and increased economic activities.

While electricity serves as the primary energy source in Bhutan, the reliance on coal and petroleum products highlights a significant dependence on fossil fuels to meet the country's energy needs. Energy efficiency measures and exploration of sustainable alternatives are essential in the Industry Sector to mitigate this reliance. The Building and Transport Sectors also play significant roles in energy consumption, emphasizing the importance of energy-efficient building designs, efficient lightings, efficient heating/cooling systems and transportation systems.

In the Building Sector, biomass (particularly fuelwood) remains the primary fuel, predominantly used for residential cooking and space heating, particularly in rural areas. Electricity is also used for heating and cooling purposes, while LPG is commonly used for cooking. Similarly, in the institutional and commercial segments, fuelwood and electricity play significant roles in heating and cooking. Implementing energy efficiency measures, promoting renewable energy sources, and adopting efficient cooking and heating/cooling systems are key to enhancing sustainability in this Sector. With policy interventions, the traditional use of fuelwood is expected to reduce but at a slower pace in rural areas over the years.

In the Industry Sector, electricity takes precedence as the primary energy source, followed by coal and derivatives, and biomass, with charcoal consumption being prominent. Kerosene and diesel have relatively smaller shares of fuel consumption. High voltage industries dominate energy consumption, indicating a heavy reliance on energy-intensive processes. Given the Sector's substantial energy consumption growth, there is a pressing need for more sustainable practices to mitigate environmental impacts. Efforts should focus on promoting renewable energy sources, improving energy efficiency, and reducing reliance on fossil fuels.

The Transport Sector exhibits significantly higher energy demands in road transport as compared to aviation. Road transport relies on a combination of electricity, diesel, and petrol, while aviation primarily relies on kerosene. Sustainable solutions, such as exploring alternative energy sources, promoting electric vehicles, and implementing fuel efficiency measures, can address the substantial energy demands of road transport and reduce environmental impact. It is expected that the adoption of

electric vehicles can bring about significant changes in the energy balance scenario in Bhutan.

Effective monitoring and management of the Energy Sector will be crucial to ensure a sustainable and balanced energy supply and demand in the future. This will involve diversifying the energy mix, promoting energy efficiency measures, and considering renewable energy sources such as solar, wind, small hydropower plants, and biogas systems. Continued policy intervention is necessary to tap into the potential of these renewable energy sources and further enhance their utilization. This is particularly important considering the long-term risks associated with mega hydro projects. By prioritizing policy measures that promote and support the development of alternative renewable energy sources, Bhutan can ensure a more diversified and sustainable energy landscape for the future.

At the same time, by embracing cleaner technologies and implementing energy conservation practices, Bhutan can achieve a more sustainable and environmentally friendly energy landscape. Energy efficiency interventions are expected to reduce the demand for diesel, petrol, and other fossil fuels, while the demand for electricity in the Industrial Sector is expected to remain significant. Furthermore, as Bhutan advances its infrastructure to facilitate the widespread adoption of electric vehicles, there will be a gradual increase in electricity demand in the Transport Sector. This shift towards cleaner and more sustainable modes of transportation aligns with the country's energy efficiency and environmental objectives.

By prioritizing renewable energy sources, improving energy efficiency, and reducing reliance on fossil fuels, Bhutan can mitigate environmental impacts, enhance energy security, and achieve its long-term sustainability goals. The integration of solar, biogas, and waste-to-energy solutions holds promise for diversifying the energy mix and contributing to a more sustainable future for Bhutan. Indeed, the current energy consumption pattern in Bhutan highlights a significant share of electricity in the fuel mix as the primary energy source, indicating a shift from traditional fossil fuels such as coal, diesel, and biomass. This shift towards electricity as a dominant energy source is expected to persist in the future, resulting in a further decrease in the country's dependence on conventional fuels.

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APPENDIX 1: INSTITUTIONAL STRUCTURE

In Bhutan, the planning and coordination of energy-related activities primarily fall under the purview of four ministries: the Ministry of Energy and Natural Resources (MoENR); the Ministry of Agriculture and Livestock (MoAL); the Ministry of Industry, Commerce, and Employment (MoICE); and the Ministry of Infrastructure and Transport (MoIT).

The following agencies are responsible for the planning, coordination, regulatory oversight, and implementation of energy-related policies and programs in Bhutan.

A. Planning and Coordination

Department of Energy: The Department of Energy (DoE) in Bhutan has been formed by merging the former Department of Renewable Energy and the Department of Hydropower and Power Systems. This integration has created a consolidated entity that serves as the central coordinating agency and focal point for all matters related to energy, power systems, and energy markets, including cross-border electricity trade. The DoE plays a pivotal role in shaping Bhutan's energy landscape and driving sustainable growth in the sector. The Department is structured into four constituent divisions: the Energy Strategy & Planning Division, Energy Resource Development Division, Power Systems & Market Division, and Energy Innovation & Management Division.

Department of Trade: The Department of Trade (DoT) under MoICE has a vision to lead the growth of a dynamic Trade Sector, ultimately bringing greater prosperity to the nation. Its mission is to create an open and liberal environment that supports the growth of the Trade Sector. This includes facilitating the integration of the nation into the regional and global trading system, stimulating the growth of the export sector, and enhancing export earnings. Furthermore, the Department aims to promote competitive and fair trade practices within the country.

Department of Geology and Mines: The Department of Geology and Mines (DGM), under MoENR undertakes essential tasks related to geological mapping and mineral exploration in Bhutan. DGM conducts geotechnical and engineering geological investigations, monitors seismic activities, and evaluates climate change-induced geo-hazards like landslides. The Department also focuses on researching Glacial Lakes and proposes measures to mitigate the risk of Glacial Lake Outburst Floods (GLOFs). Moreover, DGM plays a key role in the management and dissemination of mines and mineral information, including the tracking of coal extraction, exports, and imports within the country

Department of Industry: The Department of Industry (DoI) is responsible for facilitating industrial development in the country. It fulfills this role by formulating, implementing, and evaluating policies and programs designed to facilitate the expansion, progress, and diversification of industries for the overall advancement of the economy. Additionally, the

Department actively supports industrial transformation through the promotion of innovation, investment, and the utilization of emerging technologies. It also plays a pivotal role in promoting Bhutan as an attractive investment destination and providing support for the growth of foreign direct investments (FDIs). Through conducting thorough studies, analysis, and the development of comprehensive plans, projects, and programs, the Department aims to drive and enhance industrial development in Bhutan. The erstwhile Department of Cottage and Small Industry is merged with the Department.

Department of Forests and Park Services: The Department of Forests and Park Services (DoFPS), under MoENR envisions sustaining and conserving a healthy forest ecosystem for a progressive nation. The department's mission is to conserve and manage Bhutan's forest resources, ensuring socio-economic and environmental well-being with a minimum of 60 percent forest cover across the land. Their mandates include sustainable forest management, enhancing biodiversity and ecosystem services, facilitating integrated watershed management, promoting science-based practices, conducting forestry research, and monitoring forest resources for sustainable management and information dissemination.

Department of Livestock: The Department of Livestock (DoL), under MoAL is dedicated to ensuring food security, self-sufficiency, and improved rural livelihoods through the sustainable development of the livestock sector. Their vision is to achieve these goals by increasing livestock productivity and delivering prompt and appropriate technologies and services. The Department's mandates encompass a range of responsibilities, including the development of effective policies, the coordination and evaluation of livestock development programs, and the safeguarding of animal health and welfare.

Department of Environment and Climate Change: The Department of Environment and Climate Change (DECC) serves as the secretariat to the National Environment Commission and is responsible for various mandates. These include developing environmental policies, laws, and programs, integrating environmental considerations into development plans, raising environmental awareness, monitoring air and water quality, conducting environmental research, and coordinating international environmental agreements. DECC plays a crucial role in ensuring the protection and sustainable management of Bhutan's environment and addressing climate change challenges.

B. Regulatory Authorities

Electricity Regulatory Authority: The Electricity Regulatory Authority (ERA) of Bhutan is an electricity regulatory agency. Its primary goal is to promote fair access to electricity and safeguard the interests of the public, customers, and participants in the Electricity Sector. ERA's pivotal role involves maintaining a well-regulated and efficient electricity industry

that caters to the needs of the public and supports the sustainable development of Bhutan's energy system.

Bhutan Construction and Transport Authority: The merger of the Road Safety and Transport Authority and the Department of Roads has resulted in the formation of the Department of Surface Transport. This consolidation has brought together the regulatory responsibilities previously held by the Department of Roads, Road Safety and Transport Authority, and Construction Development Board, which are now incorporated into the Bhutan Construction and Transport Authority (BCTA). The authority envisions becoming a highly proficient organization dedicated to safeguarding lives and improving livelihoods through the establishment of a secure, dependable, robust, and efficient construction and surface transport sector in the country.

C. Operating Players

Druk Green Power Corporation Limited: Druk Green Power Corporation Limited (DGPC) is a government-owned enterprise formed in 2008 under the Companies Act of Bhutan. As a subsidiary of Druk Holding and Investments (DHI), DGPC specializes in the development and operation of generating plants including hydro, solar and wind power plants. In addition to managing these facilities, DGPC also plays a key role as a bulk trader, facilitating the export of excess electricity.

Bhutan Power Corporation Limited: The Bhutan Power Corporation Limited (BPC) is a government-owned utility company in Bhutan entrusted with the crucial tasks of electricity transmission, distribution, and supply. Additionally, BPC plays a vital role in establishing an Associated Transmission System to integrate the national power grid and facilitate the export of excess electricity. BPC's establishment in January 2002 was mandated by the Corporatization Act of Bhutan 2000, which aimed to transform the power sector from a government department into a corporate entity.

Natural Resources Development Corporation Limited: The Bhutan Logging Corporation, established in 1984, aimed to enhance sustainable forest resource management. Over time, it transformed into the Natural Resources Development Corporation Limited (NRDCL), broadening its commercial scope to include timber, sand, stone, and other natural resources. As a government-owned entity under DHI, NRDCL adheres to the Companies Act of Bhutan, prioritizing efficiency, skilled workforce, and environmental consciousness. In April 2021, the Wood Craft Centre Limited was merged with NRDCL, leading to an expansion in the company's size and activities.

APPENDIX 2: CONVERSION FACTORS

Sl. No	Fuel	Basic unit	TOE
1	Anthracites	MT	0.6377
2	ATF (Jet Kerosene)	kl	0.85055
3	Bamboo chips	MT	0.2771
4	Biogas	MT	1.2038
5	Briquettes	MT	0.2771
6	Calcined petroleum coke	MT	0.7762
7	Charcoal	MT	0.7046
8	Chinese gas coke	MT	0.6735
9	Coke/ Semi coke/ Carbon raiser	MT	0.6735
10	Electricity	GWh	85.9845
11	Fuel wood	MT	0.3726
12	Furnace oil	kl	0.8578
13	Gas/Diesel oil	kl	0.8935
14	High speed diesel	kl	0.8935
15	Industrial gas	MT	0.2412
16	Kerosene	kl	0.8578
17	LAMC	MT	0.6735
18	Light diesel oil	kl	0.8729
19	LPG	MT	1.1297
20	Non coking coal (Nangal coal)	MT	0.2842
21	Other Coal (Lignite)	MT	0.28422
22	Petrol (Motor Gasoline)	kl	0.8147
23	RPC	MT	0.6735
24	Sub bituminous	MT	0.4514
25	Wood (Fuelwood and Briquette)	MT	0.37259
26	Wood chips	MT	0.2771

Department of Energy
Ministry of Energy and Natural Resources
Royal Government of Bhutan

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