2025

Energy Sector Synopsis Report 2081/82

Madhesh Province

Prepared For :
Ministry of Energy, Irrigation and Water Supply,
Janakpurdham, Dhanusha

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Critical Insights and Strategic Recommendations

The Energy Sector Synopsis Report 2081/82 of Madhesh Pradesh provides a comprehensive analysis of the energy landscape in one of Nepal's most densely populated and agriculturally significant provinces. The findings underscore the province's unique position within Nepal's energy framework, characterised by high grid penetration, heavy reliance on traditional biomass, and significant dependence on imported fossil fuels.

Key findings

Madhesh Province, despite being Nepal's smallest by area, plays a pivotal role in the nation's economic and demographic landscape, contributing 13.1% to Nepal's GDP in FY 2023/24 with a population of 6.14 million. The energy balance for FY 2081/82 reveals a primary energy supply of 95,408 TJ, with biomass dominating at 34,249 TJ (primarily fuelwood at 20,455 TJ) and imported petroleum products contributing 47,117 TJ. The residential sector is the largest energy consumer, accounting for 75% of the total demand (213,367 TJ), predominantly through biomass (199,240 TJ from fuelwood). The transportation sector relies almost entirely on petroleum products (11,349 TJ), while the industrial, agricultural, and commercial sectors also show significant fossil fuel and biomass consumption.

The province's energy consumption patterns highlight a critical dependency on traditional and imported energy sources. Biomass, constituting 73% of total consumption, drives residential energy use, particularly for cooking and heating, contributing to environmental degradation, deforestation, and health issues due to indoor air pollution. The transportation sector's near-total reliance on imported fossil fuels underscores vulnerabilities to global price volatility and supply chain disruptions, straining Nepal's foreign currency reserves. Electricity, while increasingly significant, contributes only 2.23% to the energy mix, despite high grid penetration in the province, indicating underutilization of cleaner energy sources.

Madhesh Province's renewable energy potential, particularly solar, stands out as a significant opportunity. With an estimated solar potential of 149.7 GW, the highest among Nepal's provinces, and 2,140 MW of utility-scale solar projects in development, the province is well-positioned to diversify its energy mix. However, the negligible wind energy potential (1.9 MW) and absence of hydropower or geothermal development limit other renewable options.

Energy efficiency and infrastructure challenges further complicate the province's energy landscape. Significant distribution losses, particularly for diesel (12,569 TJ in FY 2081/82), highlight inefficiencies in the supply chain. The per capita electricity consumption of 312 kWh in FY 2081/82, below the national average of 370 kWh, reflects limited access to modern energy services despite high grid penetration. Pricing trends for petroleum products show relative stability, while electricity tariffs remain structured to support diverse consumer categories, yet affordability and reliability remain concerns for widespread adoption.

Challenges

- **Over-reliance on biomass:** The dominance of biomass in residential consumption (78.7% of the energy mix) perpetuates environmental degradation, including a 1.4% deforestation rate from 2001 to 2023, and contributes to health issues from indoor air pollution, disproportionately affecting women and children. Transitioning to cleaner alternatives like electric or biogas cookstoves faces barriers due to cultural preferences, high upfront costs, and limited awareness.

- **Fossil fuel dependency:** The transportation and industrial sectors' reliance on imported petroleum products (47,117 TJ in FY 2081/82) poses risks to energy security, exposing the province to global market fluctuations and geopolitical uncertainties. Nepal's lack of domestic fossil fuel reserves exacerbates this vulnerability.

- **Infrastructure limitations:** Despite high electrification, the quality of electricity supply is inconsistent, with rural areas experiencing outages and voltage fluctuations. Significant distribution losses, particularly for diesel, indicate inefficiencies that require substantial investment in grid modernisation and supply chain optimisation.

- **Underutilised renewable potential:** While solar potential is substantial, the province has yet to fully capitalise on it due to financial constraints, limited technical expertise, and insufficient policy incentives.

- **Financial barriers:** Developing renewable energy infrastructure and transitioning to clean cooking solutions require significant investment, which is challenging given Nepal's financial constraints.

Key Recommendations

Madhesh Province's energy challenges are matched by significant opportunities, particularly in leveraging its solar potential and aligning with Nepal's ambitious energy and climate goals, such as the Energy Development Roadmap 2081 BS and the Nationally Determined Contribution (NDC) 3.0. The following recommendations build on the report's high-level and short-term solutions to address these challenges:

- **Promote electric cooking and grid strengthening:** Biomass (fuelwood, agriculture residue and animal dung) forms the majority of the energy demand of Madhesh province in FY 2081/82 at 208,141 TJ (73% of the total energy demand of the province). However, biomass fuels cause indoor air pollution, deforestation, low energy efficiency, and health issues, especially for women and children, while contributing to environmental degradation and time-consuming fuel collection. Hence, Madhesh province should promote electric and clean cookstoves, expand access to electricity, encourage the adoption of biogas and solar cookers, and raise awareness. However, promotion of electric cooking should come hand in hand with a reliable power distribution infrastructure, requiring coordination with the Nepal Electricity Authority.

- **Scale decentralised solar solutions:** Madhesh province has a high potential to promote renewable energy technologies such as solar. Its solar potential stands the highest among all other provinces of Nepal, i.e. 149.7 GW (see Section 4.3). The provincial government should promote solar rooftop systems & Battery Energy Storage Systems (BESS) commercial & industrial sectors, promote the development of utility-scale solar photovoltaics for the national energy mix and promote hybrid (solar + grid)

water pumping solutions for irrigation and drinking water. Public-private partnerships, as emphasised in the 16th Five-Year Plan, can mobilise investment for these initiatives.

- **Enhance energy efficiency:**Implementing the National Energy Efficiency Strategy 2075 BS at the provincial level can reduce energy intensity and demand. Energy audits, demand-side management, and the promotion of energy-efficient appliances in households and industries are critical. Awareness campaigns, as suggested in the report, can drive behavioural changes toward efficient energy use.

- **Diversify energy mix with bioenergy:** The province's agricultural residue (7,186 TJ) and animal dung (6,608 TJ) present significant bioenergy potential. Promoting biogas plants, as supported by the AEPC, can provide a sustainable alternative to fuelwood for cooking and reduce environmental impacts. Research into waste-to-energy systems, as outlined in the NDC, can further diversify the energy mix.

- **Strengthen policy and institutional coordination:** Effective implementation requires robust coordination between provincial and national institutions, including the Ministry of Energy, Irrigation and Water Supply, NEA, and AEPC. Streamlining regulatory frameworks and enhancing technical capacity, as proposed in the White Paper 2075 BS, will support project execution. Engaging local governments in decentralised energy planning, as per the Rural Energy Policy 2006, can ensure community-driven solutions.

- **Mobilise climate finance:** Nepal's LTS for Net-Zero Emissions estimates a need for USD 33.04 billion by 2030 for NDC implementation. Madhesh Province should leverage international climate finance to support renewable energy projects and climate-resilient infrastructure. Domestic resource mobilisation, including green bonds and private sector investment, can bridge funding gaps.

- **Alignment with national and global goals:** Madhesh Province's energy strategy aligns with Nepal's broader energy and climate commitments. The Energy Development Roadmap 2081 BS targets 28,500 MW of installed capacity by 2035, with a focus on renewable energy and electrification. The emphasis on clean cooking and energy efficiency aligns with SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), while gender-focused interventions address SDG 5 (Gender Equality).

Solutions with further research

- **Battery Energy Storage Systems:** Battery Energy Storage Systems are becoming feasible due to falling technology costs, improved efficiency, supportive policies, and growing revenue streams from grid services and renewable energy integration. Battery energy storage systems stabilise the grid by storing excess energy, balancing supply and demand, supporting frequency regulation, enabling renewable integration, and providing backup during outages or peak demand. Madhesh province should explore strengthening its power grid with the integration of Battery Energy Storage Systems in both the commercial & industrial sectors, and the utility grid. This initiative requires coordination with the Nepal Electricity Authority.

- **Other renewables:** Compared to the total solar energy potential of Madhesh province, the wind energy potential is low, at only 1.9 MW (for windspeed ≥ 5 m/s and other realistic restrictions, see Section 4.3). Thus, Madhesh province should conduct a micro-siting assessment of specific areas with high potential for wind energy to collect long-term wind resource data with a thorough feasibility study.

  Similarly, in regard to other renewables such as geothermal energy, the studies of potential geothermal sites in Nepal are in the hilly and mountainous region, such as in Sankhuwasabha, Manang, Myagdi, and Mustang districts. Studies on geothermal potential in the Madhesh province haven't been done. At present, there is no substantial electricity generation from geothermal sources in Nepal. As Madhesh province aims to diversify its energy mix, it may explore its geothermal potential by conducting research studies. However, Madhesh province currently stands to benefit more from renewable energy sources such as solar, which has a high potential to scale.

Path forward

Madhesh Province stands at a critical juncture in its energy transition. Its high population density, agricultural prominence, and solar potential position it as a key player in Nepal's sustainable development. However, overcoming reliance on biomass and fossil fuels requires concerted efforts in policy implementation, infrastructure development, and community engagement. By prioritising electric cooking, scaling solar energy, and enhancing energy efficiency, the province can reduce environmental and health impacts while fostering economic growth. Strengthening institutional coordination and mobilising climate finance will be crucial to realising these ambitions.

In conclusion, the Energy Sector Synopsis Report 2081/82 highlights Madhesh Province's potential to lead Nepal's renewable energy transition. By addressing its challenges and capitalising on its opportunities, the province can achieve energy security, contribute to national climate goals, and improve the quality of life for its 6.14 million residents, paving the way for a sustainable and prosperous future.

Table of Contents

List of Abbreviations

AD	Anno Domini
AEPC	Alternative Energy Promotion Centre
ATF	Aviation Turbine Fuel
BESS	Battery Energy Storage Systems
BOOT	Build, Operate, Own, and Transfer
B.S	Bikram Sambat
CBS	Central Bureau of Statistics
CREF	Central Renewable Energy Fund
DF	Diesel Fuel
DMG	Department of Mines and Geology
DoC	Department of Customs
DoED	Department of Electricity Development
DP	Domestic Purpose
EVs	Electric Vehicles
FRTC	Forest Research and Training Centre
GESI	Gender Equality and Social Inclusion
GJ	Gigajoule
GWh	Gigawatt-hour
GHG	Greenhouse Gas
HSD	High-Speed Diesel
ICS	Improved Cook Stoves
IEA	International Energy Agency
IPPAN	Independent Power Producers' Association Nepal
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt-hour
LPG	Liquefied Petroleum Gas
LT-LEDS	Long-Term Low Greenhouse Gas Emission Development Strategy
LTS	Long-Term Strategy
LULUCF	Land Use, Land-Use Change, and Forestry

M&E	Monitoring and Evaluation
MVA	Megavolt-ampere
MW	Megawatt
MLMCPA	Ministry of Land Management, Cooperatives and Poverty Alleviation
MoALD	Ministry of Agriculture and Livestock Development
MoEWRI	Ministry of Energy, Water Resources, and Irrigation
MoFE	Ministry of Forest and Environment
MoF	Ministry of Finance
MoHP	Ministry of Health and Population
MS	Motor Spirit
NAP	National Adaptation Plan
NBNL	Nepal Ban Nigam Ltd.
NDC	Nationally Determined Contributions
NEA	Nepal Electricity Authority
NOC	Nepal Oil Corporation
NPR	Nepalese Rupee
NSO	National Statistics Office
PJ	Petajoule
PPPs	Public-Private Partnerships
RETs	Renewable Energy Technologies
SDGs	Sustainable Development Goals
SEMAN	Solar Electric Manufacturers Association Nepal
SKO	Superior Kerosene Oil
TJ	Terrajoule
T&D	Transmission & Distribution
TOE	Tons of Oil Equivalent
UNFCCC	United Nations Framework Convention on Climate Change
WECS	Water and Energy Commission Secretariat

List of Figures

List of Tables

1 Introduction

1.1 Energy Scenario of Nepal

Nepal is a country with immense energy potential but significant challenges in meeting its growing energy demands. With a population of approximately 30 million, Nepal's energy sector is critical for economic growth, poverty reduction, and sustainable development.

Nepal's energy mix is characterised by a heavy reliance on renewable and traditional sources, with limited use of fossil fuels due to the absence of domestic reserves. The primary energy sources include:

Hydropower

Nepal's mountainous terrain and abundant river systems make it a hydropower powerhouse. The country is often called the "water tower of South Asia" due to its vast water resources. Hydropower accounts for the majority of the electricity generation. In 2024, Nepal's installed hydropower capacity was 2,990 MW, which is 95% of the total installed generation capacity (NEA, 2024).

Biomass and Biofuels

Traditional biomass, including firewood, agricultural residues, and animal dung, dominates Nepal's energy consumption, particularly in rural areas. Approximately 67% of total primary energy consumption comes from biomass, with 21 million people relying on it for cooking (IEA, 2025). This heavy dependence contributes to deforestation, with an estimated 10 million tons of wood consumed unsustainably each year.

Fossil Fuels

Nepal lacks significant oil, gas, or coal reserves, making it entirely dependent on imported petroleum products, primarily from India. Fossil fuels constitute about 26.5% of the energy mix, with diesel, kerosene, and gasoline being the main imports (IEA, 2025). Fossil fuel makes up the majority of the transportation and agriculture sector energy consumption, with 99% in the transportation sector (petrol, diesel, aviation turbine fuel and liquefied petroleum gas combined) and 77% in the agriculture sector (petrol and diesel combined) (WECS, 2024).

Other Renewables

Nepal is increasingly exploring solar, wind, and biogas as alternative energy sources. The country receives ample solar radiation (3.6 to 6.2 kW/m²/day), making solar energy a viable option. In recent developments, Nepal Electricity Authority has allocated an additional 960 MW of utility-scale solar plants across 64 projects. Wind energy remains underdeveloped but holds potential in certain regions.

Table 1: Energy consumption for FY 2079/80 (WECS, 2024)

Energy Source	Share of Energy Mix (%)	Key Characteristics
Grid electricity	7.2%	Majority hydropower
Tradional	63.9%	Biomass and waste, primarily for cooking/heating, cause deforestation
Commercial	25.8%	Includes fossil fuels such as coal and petroleum products
Renewables	3.1%	Solar, solar-wind hybrid, biogas and micro/pico hydro

1.1.1 Energy Production and Consumption

Energy Production

Nepal's energy production is primarily driven by hydropower, with limited contributions from other sources. In 2024, total electricity consumption reached 13,966 GWh, up from 12,369 GWh in 2023 (NEA, 2024). The installed hydropower capacity of 2,990 MW generates the bulk of this electricity, though seasonal variations lead to reduced output during dry months. Biomass production is decentralised, with households managing their fuelwood supplies. Nepal also exports hydroelectricity to India during the wet season, with 1,946 GWh exported in 2024, which is an increase of 44.6% from the previous year (NEA, 2024).

Energy Consumption

Nepal's total energy consumption in 2079/80 BS was 532.4 PJ (WECS, 2024). By 2024, per capita electricity consumption had risen to 400 kWh (Nepal Government, 2024). The residential sector dominates consumption, using biomass for cooking and heating, while the industrial and transportation sectors rely on imported fossil fuels. Despite progress, per capita energy consumption remains low, less than one-fifth of the global average (The World Bank, 2025).

Energy Access

Electricity access has seen remarkable improvement, with 98% of the population connected to the grid or off-grid systems by 2024 (Nepal Government, 2024). However, the quality of supply varies, with rural areas experiencing frequent outages and voltage fluctuations. Clean cooking access remains a challenge, with 21 million people still using traditional biomass, contributing to health and environmental issues.

Energy Infrastructure

Nepal's energy infrastructure is undergoing significant expansion to support its growing energy needs and export ambitions. Key components include:

- **Transmission and Distribution**: As of 2024, Nepal has 6,508 circuit kilometres of transmission lines and substations with a capacity of 13,050 MVA (NEA, 2024). The government plans to expand these to 17,446 circuit kilometres and 40,000 MVA by 2035 (Nepal Government, 2024).
- **Institutions**: The Nepal Electricity Authority (NEA) manages electricity transmission and distribution, while the Water and Energy Commission Secretariat (WECS) oversees policy formulation and data collection. The Alternative Energy Promotion Centre (AEPC) promotes renewable energy technologies.

Challenges in the Energy Sector

Despite progress, Nepal faces several challenges in its energy sector:

- **Energy Security**: Reliance on imported fossil fuels and seasonal hydropower variability threatens energy security. Nepal's import dependency strains its economy, with significant foreign currency spent on petroleum products.
- **Infrastructure Gaps**: Limited transmission and distribution infrastructure hinders a reliable electricity supply, particularly in rural areas. Load shedding remains a concern during peak demand periods.

- **Environmental Impact**: Heavy biomass use contributes to deforestation, with an estimated 1.4% deforestation rate from 2001 to 2023 (Global Forest Watch, 2025). This exacerbates environmental degradation and greenhouse gas emissions.
- **Financial Constraints**: Developing large-scale hydropower projects requires substantial investment, which Nepal struggles to mobilise domestically. Attracting foreign investment and managing financial risks are critical challenges.
- **Coordination and Capacity**: Lack of inter-agency coordination and limited technical capabilities hamper project implementation.

Future Plans and Opportunities

Nepal's energy sector is poised for transformation, with ambitious plans to leverage its renewable potential and enhance energy security. Key initiatives include:

Hydropower expansion: The government aims to increase hydropower capacity to 28,500 MW by 2035 (Nepal Government, 2024), tapping into Nepal's vast untapped potential.

Electricity exports: Nepal aims to export 15,000 MW by 2035 (Nepal Government, 2024).

Renewable energy development: Solar energy is a priority, with NEA allocating an additional 960 MW in tenders for 64 projects in 2024. Biogas and improved cookstoves are being promoted to reduce biomass dependency and improve health outcomes. Wind energy, though underdeveloped, holds potential for future exploration.

Energy efficiency and clean cooking: AEPC continues to promote energy efficiency, while clean cooking initiatives aim to transition households to biogas and electric stoves, reducing reliance on firewood.

Climate resilience: Nepal's energy plans align with its climate goals, focusing on low-carbon connectivity, sustainable urbanisation, and climate-smart agriculture. Investments in resilient infrastructure and private sector engagement are critical to achieving these objectives.

Nepal's energy scenario reflects a blend of opportunity and challenge. Its vast hydropower potential positions it as a potential energy hub in South Asia, while its reliance on biomass and imported fossil fuels underscores the need for sustainable solutions. The government's ambitious *Energy Development Roadmap 2081 BS* sets a clear path toward increasing energy access, boosting consumption, and expanding exports. However, addressing infrastructure gaps, financial constraints, and environmental concerns will be crucial to realising these goals. By leveraging renewable energy and international partnerships, Nepal can achieve energy security and contribute to global climate objectives.

1.2 Geography of Madhesh Province

Madhesh Province, in southeastern Nepal, covers 9,661 km² with flat Terai plains and hilly Chure regions, elevations from about 60 to 950 meters. It borders Koshi Province to the east and north, Bagmati Province to the north, and India's Bihar state to the south and west, making it a key trade and agricultural hub.

Covering an area of 9,661 km², which accounts for approximately 6.56% of Nepal's total area of 147,181 km², it is the smallest province by area but one of the most densely populated, with a population of 6,144,600 as per the 2021 Nepal census (NSO, 2023). This high population density, at around 633 people per km² (compared to 559 in 2011), underscores its importance in demographic and economic terms (NSO, 2023).

The province includes eight districts: Parsa, Bara, Rautahat, Sarlahi, Mahottari, Dhanusa, Siraha, and Saptari, with major urban centres like Birgunj and Janakpur. It includes major rivers, such as Koshi in the eastern border, Bagmati, Kamala, Trijuga, and East Rapti, which are vital for agriculture and irrigation.

It has a subtropical climate with hot, humid summers (30-35°C) and mild winters (15-20°C), with heavy monsoon rains from June to September. The province is agriculturally rich, with 25.9% forest cover (FRTC, 2024), and hosts protected areas like Parsa National Park and Koshi Tappu Wildlife Reserve, supporting diverse wildlife.

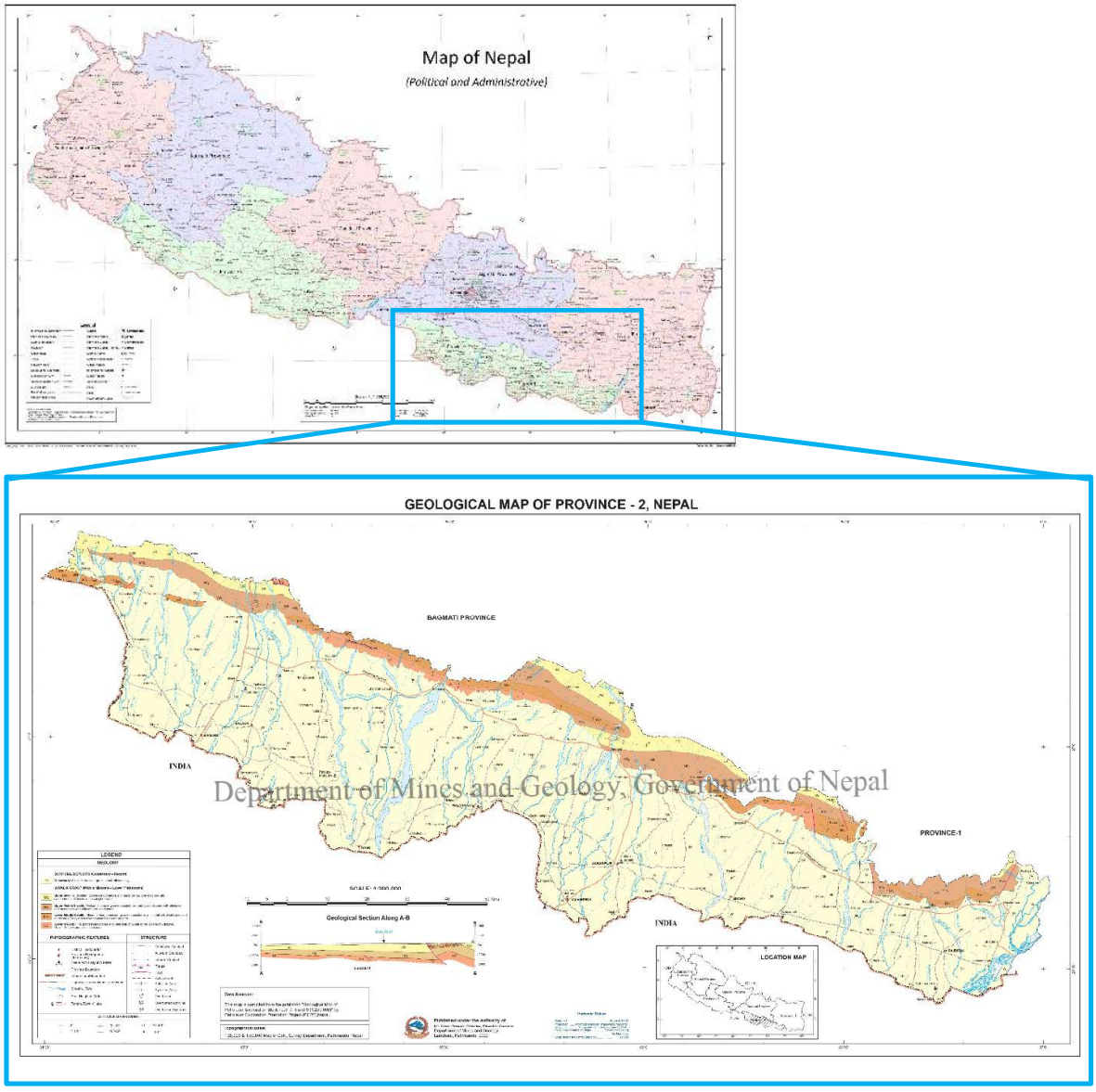


Figure 1: (Top) Nepal map (DMG, 2025), (Bottom) Madhesh Province Map, (MLMCPA, 2025)

1.3 Demography of Madhesh Province

Madhesh Province is a vibrant and densely populated area known for its agricultural productivity and cultural diversity. As one of Nepal's seven provinces, it plays a significant role in the country's demographic and economic landscape. This section provides an overview of the province's demography, drawing primarily on data from the Central Bureau of Statistics (CBS) of Nepal, particularly the 2021 National Population and Housing Census.

As of the 2021 census, Madhesh Province has a population of 6,114,600, making it Nepal's second most populous province after Bagmati (NSO, 2023). This figure represents approximately 20.4% of Nepal's total population of 29,192,480.

The gender composition is nearly balanced with 50.1% males (3,065,751) and 49.9% females (3,048,849). The sex ratio is 100.55 males per 100 females. This near parity suggests minimal gender-based demographic imbalances, though socioeconomic disparities may still exist. The province has 1,156,715 households, indicating an average household size of approximately 5.3 persons, slightly higher than the national average of 4.32 (NSO, 2023).

The age structure of Madhesh Province reflects a youthful population, with a significant proportion of children and young adults. The age group of 15 – 59 years make up 57.7% of the total population. Similarly, the population aged 14 years or below and 60 years or above are 33.2% and 9.1% (NSO, 2023).

The literacy rate for individuals aged 5 and older in Madhesh Province is 63.5%. This rate is lower than the national average, which is approximately 76.2% for the same age group. The gap highlights challenges in educational access, particularly in rural areas and among marginalised communities.

Madhesh Province is ethnically diverse. The 2021 census identifies 142 ethnic groups in Nepal, with Madhesh Province hosting a significant share. The top 10 ethnic groups in the province are Yadav, Musalman, Teli, Tharu, Koiri/Kushwaha, Chamar/Harijan/Ram, Dhanuk, Kurmi, Musahar and Dusadh/Pasawan/Pasi (NSO, 2025).

Madhesh Province is linguistically rich, with 124 mother tongues reported across Nepal in the 2021 census (Kathmandu Post). The primary languages by share of population in the province are Maithili, Bhojpuri, Bajjika, Nepali, Tharu, Urdu, Magahi, Tamang and Magar Dhut (NSO, 2025).

The religious landscape of Madhesh Province is predominantly Hindu (84.2% of the population), with significant Muslim (13.3%) and Buddhist (2.2%) minorities. Other religions, such as Christianity, Kirat, and Bon, have smaller followings (NSO, 2025).

The vast majority of residents are Nepali citizens (6,087,176), followed by Indians (27,307) and 114 from other countries (City Population, 2025).

Madhesh Province is Nepal's most agriculturally dominated region. Its demographic profile, characterised by a young population and lower literacy rates, poses both opportunities and challenges. The high dependency ratio suggests a need for economic policies that create jobs for the working-age population, while the literacy gap calls for targeted educational interventions.

The 16th Five-Year Plan outlines ambitious quantitative targets for Madhesh Province, aiming to drive economic and social development from FY 2023/24 AD to 2028/29 AD. The province targets an economic growth rate of 3.5% and a per capita GDP of USD 892, reflecting modest growth aspirations. Poverty reduction is a priority, with the population below the national

poverty line expected to decrease to 22.5%. The Human Development Index is set to improve by 0.51, alongside an the unemployment rate reduction to 20.1%. Labour force participation is targeted to rise to 39.7%, with registered large-scale industries increasing to 611. The plan also aims to boost registered micro, small, and medium-scale enterprises to 118.8 thousand, and the population per bank/financial institution branch to 3,459. These targets highlight a focus on economic diversification and social welfare, though challenges in implementation may affect outcomes.

1.4 Economy of Madhesh Province

In the fiscal year 2023/24, Madhesh province contributed 13.1% of the total Gross Domestic Product (GDP) (MoF, 2024). This ranks 4th out of the 7 provinces of Nepal, with the highest contribution from the Bagmati province at 36.4% of the GDP and Karnali having the lowest contribution at only 4.3%. The total GDP of Nepal in 2023/24 is NPR 5,704.8 billion (MoF, 2024).

Agricultural sector contributed 35.3% to the total GDP of the Madhesh province in 2023/24. This proportion of agricultural sector contribution is the highest compared to other provinces. The service sector contributes 53.9% and industry contributes 10.8% of the total province's GDP (MoF, 2024).

In terms of the per capita GDP, Madhesh province is expected to be the lowest at $892 in 2023/24. The average per capita GDP of Nepal is $1,434. Bagmati province has the highest per capita GDP at $2,484. Madhesh province, however, ranks second in the provincial revenue at NPR 13,380 million, just second to Bagmati province with NPR 25,940 million revenue (MoF, 2024).

Madhesh province has 86,089 small, domestic, and cottage industries, making up 14.6% share of Nepal’s total (589,854 industries) in 2023/24. This ranks 4th among other provinces, with Bagmati having the highest number of small, domestic, and cottage industries with 173,862 (29.5% of the country total) (MoF, 2024).

The economic survey of 2023/24 reports electricity access to 100% of the population of the Madhesh province; however, a stocktake of the actual use of electricity by the population required further research. This is despite its low provincial power generation capacity at only 25 MW (including only those from Nepal Electricity Authority) (MoF, 2024).

Overall, the economic growth rate of Madhesh province stands at 3.8% which is on par with the national average at 3.87% in 2023/24. Madhesh province ranks 4th among other provinces in economic growth rate, with Gandaki province having the highest rate at 4.6% (MoF, 2024).

The economic and social indicators of Madhesh province are shown in Table 2.

Table 2: Economic and social indicators of Madhesh province (MoF, 2024)

Index	Madhesh Province
Administrative and Demographic Situation	
Number of local levels	136
Population (in percent)	21.1
Area (in percent)	6.6
Economic and social sector	
Economic growth rate (at basic prices) in percent	3.8
Provincial contribution to domestic product (at consumer prices)	13.1
GDP per capita (in US dollars)	892
Number of small, cottage and small industries	86.1
Registration number of the industry (000)	22
Hydropower generation	25
Forest area (in percent)	3.9
School number	4,806
Financial sector	
Number of banks and financial institutions' branches	1,778
Population per branch	3,439
Number of insurer branches	372
Provincial expenditure (in Rs. 10 million)	2,687
Province revenue (in Rs. 10 million)	1,338
Accumulated fund savings (mid July 2024) (10 million)	1,552

2 Literature review

2.1 Energy classification trend

The classification of energy in this synopsis report aligns with that described by WECs in the Energy Sector Synopsis Report 2024 (FY 2079/80). The energy sources have been classified into three categories: (i) traditional, commercial and modern renewables. Fuelwood, agriculture residue, animal dung (animal waste), and other biomass (bagasse) are classified under traditional resources. The terms fuelwood and firewood are used synonymously. Similarly, coal, hydropower, and petroleum products are categorised under commercial resources. Petrol, diesel, kerosene, etc., fall under petroleum products. Finally, wind, solar, biogas, mini/micro and pico hydropower are classified under modern renewables (Figure 2).

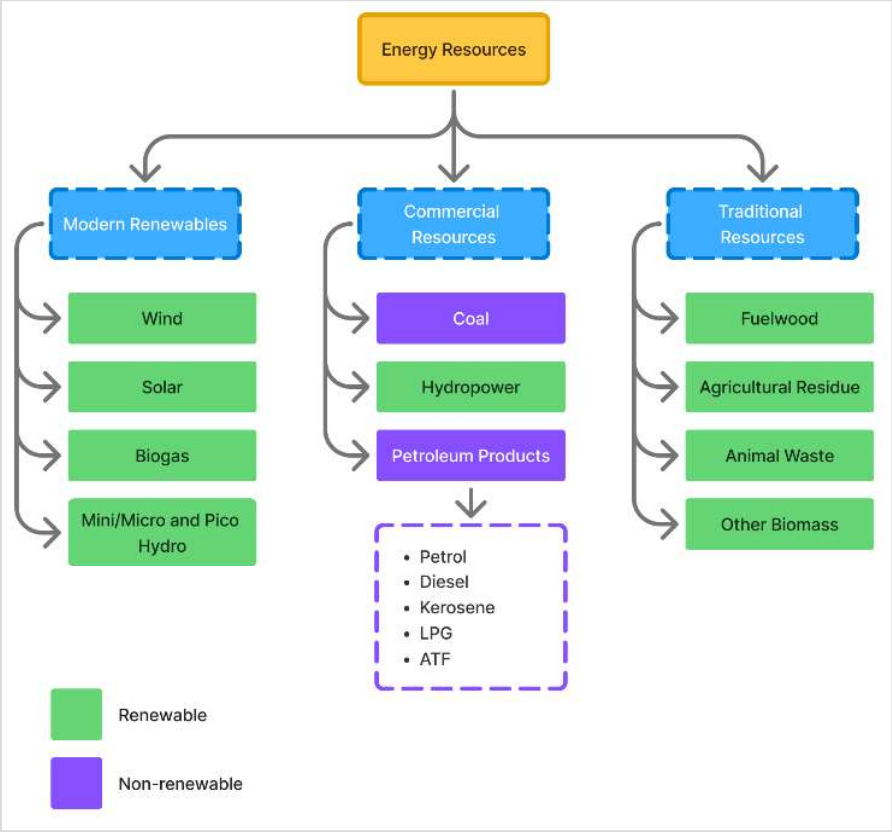


Figure 2: Classification of energy resources as per WECS Energy Sector Synopsis Report 2024

2.2 Overview of the Energy Outlook of Other Nations

2.2.1 SAARC Nations

2.2.1.1 Afghanistan

Afghanistan's installed electricity generation capacity stands at 1,097 MW as of 2024. Renewables, primarily hydropower, dominate with 55.88% (613 MW), followed by power imports at 27.35% (300 MW). Fossil fuels contribute minimally, with oil/diesel at 9.12% (100 MW), gas at 4.01% (44 MW), and coal and others at 3.65% (40 MW). The heavy reliance on renewables and imports reflects Afghanistan's limited domestic fossil fuel reserves and ongoing efforts to enhance energy access through regional cooperation. Total energy consumption is estimated at approximately 20 PJ in 2023, primarily from imported petroleum and biomass.

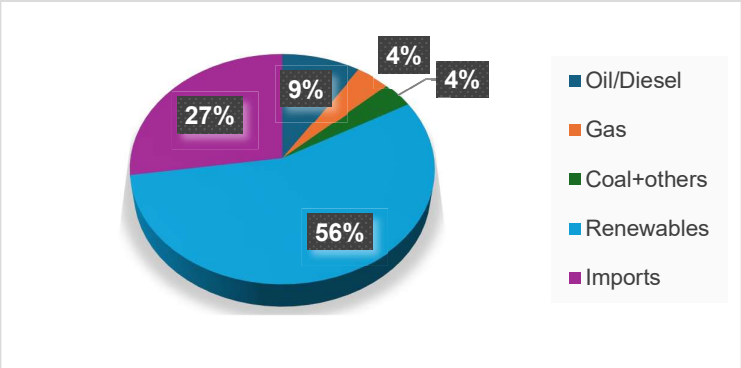


Figure 3:Afganistan's total energy supply in 2023/24 (IRENA, 2023)

2.2.1.2 Bangladesh

Bangladesh's energy sector remains dominated by fossil fuels. As of June 2023, the total installed capacity stood at 24,911 MW, with gas accounting for nearly half of the capacity, followed by furnace oil, coal, diesel, and power imports. Renewable sources such as hydro and solar PV made up less than 3% of the total mix. In FY 2022–23, electricity generation reached around 88,450 GWh. Gas remained the primary source, contributing over half of the generation, followed by furnace oil, coal, and imports. Renewables and hydro contributed marginally. Sector-wise, electricity consumption was led by the domestic sector, followed by industrial, commercial, and agricultural use. Despite some progress in renewables, the country's power system is still heavily reliant on gas and oil, with growing demand placing pressure on energy diversification efforts.

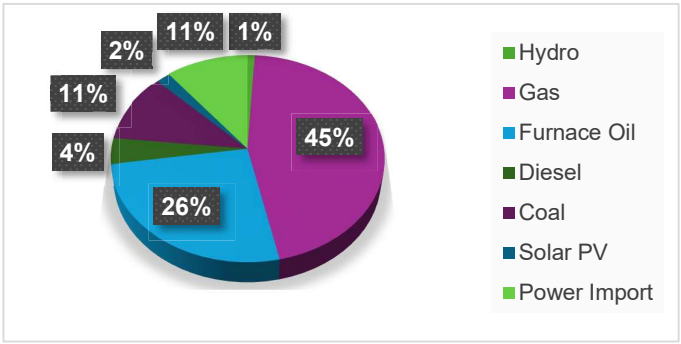


Figure 4: Bangladesh's source-wise Installed Capacity (2023-24) (BPDB, 2023)

2.2.1.3 India

India's energy sector continues its transition toward renewables, with total installed electricity capacity reaching 467,884 MW as of March 31, 2025. Fossil fuels still hold a slight majority, accounting for just over half of the capacity, with coal alone comprising the largest share. Non-fossil sources, including hydro, wind, solar, biomass, and nuclear, collectively make up nearly 49% of the total mix, indicating a strong shift toward cleaner energy.

In FY 2023–24, the total primary energy supply was estimated at 37,812 PJ, with coal remaining the dominant source, followed by oil, natural gas, biomass, and renewables. Despite rapid renewable capacity additions, coal continues to play a central role in the energy mix (WEC, 2024).

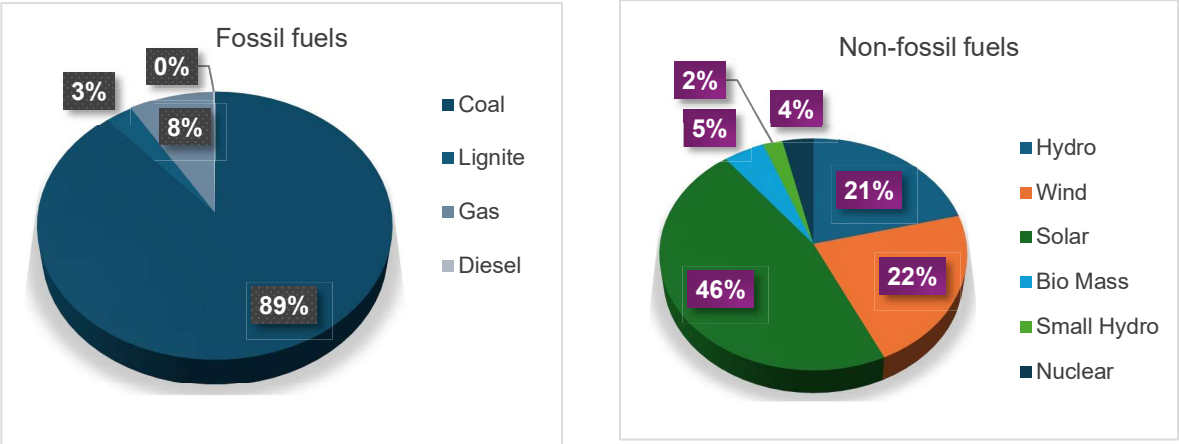


Figure 5: India's source-wise consumption capacity in 2024 (MoSPI, 2025)

Electricity generation stood at approximately 1,953,000 GWh, with sector-wise consumption patterns showing industry as the largest consumer, followed by domestic, agricultural, and commercial sectors. The growing contribution from solar and wind marks a significant step in India's energy diversification efforts towards renewable energy sources.

2.2.1.4 Maldives

The Maldives, an island nation, relies heavily on imported fossil fuels due to the absence of domestic reserves. The total installed electricity capacity stands at 601 MW, with diesel accounting for 532 MW (88.52%) and renewables contributing 69 MW (11.48%), predominantly solar. In 2020, the country imported approximately 723,000 tons of refined petroleum products, distributed across its inhabited islands. Diesel fuels electricity generation, industrial processes, and maritime transport, while petrol supports road transport and aviation, and liquefied petroleum gas (LPG) is increasingly replacing biomass for cooking. The nation holds significant potential for renewable energy, including solar, wind, and ocean sources. The Road Map for the Energy Sector 2020–2030 (2020) sets an initial target of 37 MW from renewables, with recent progress including 3 MW of rooftop solar PV installations in the Greater Male Region by 2022. This, alongside diesel generators and additional renewable systems totalling 21.5 MW, enabled universal electricity access by 2022.

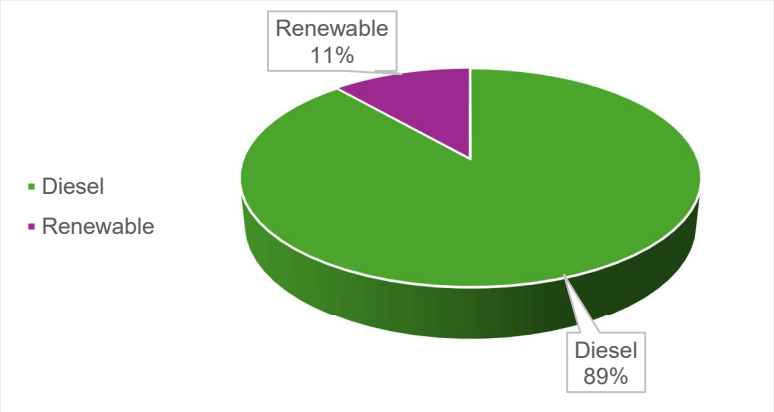


Figure 6: Maldives source-wise installed capacity (MoCCEE, 2022)

2.2.1.5 Bhutan

Bhutan's energy sector is almost entirely powered by renewables, with hydropower contributing over 99% of the total installed capacity of 2,357 MW as of 2023. Solar and wind make up the remaining share, with small-scale developments underway. The country exports a significant portion of its hydroelectricity to India, making energy a key driver of its economy. Electricity access is nearly universal, and per capita consumption is among the highest in the region. While the hydro dominates, Bhutan is gradually expanding into solar and exploring green hydrogen.

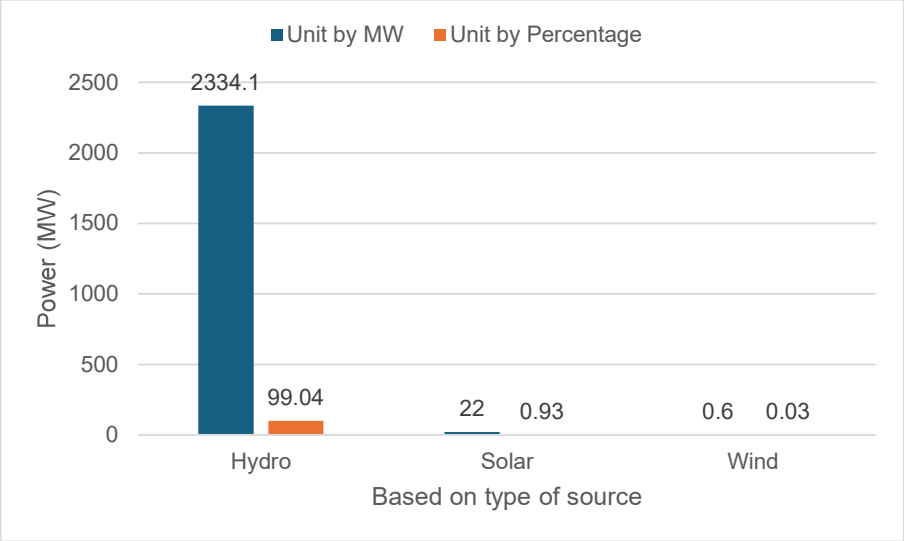


Figure 7: Solar electricity generation in 2023 (MoENR, 2022)

2.2.1.6 Pakistan

As of 2024, Pakistan's total installed electricity generation capacity stands at 49,270 MW. Fossil fuels remain the dominant source, contributing around 58% of capacity, which is primarily from gas, coal, and diesel. Non-fossil sources account for over 41%, led by hydro and supported by nuclear, wind, solar, and biomass. Net-metered solar systems have also seen significant growth, contributing more than 5% to the total mix. Renewables now make up nearly one-third of installed capacity, reflecting a gradual shift in energy planning. Electricity consumption is primarily driven by the industrial and domestic sectors, highlighting the importance of energy reliability and diversification in meeting rising demand. (IEA, 2025)

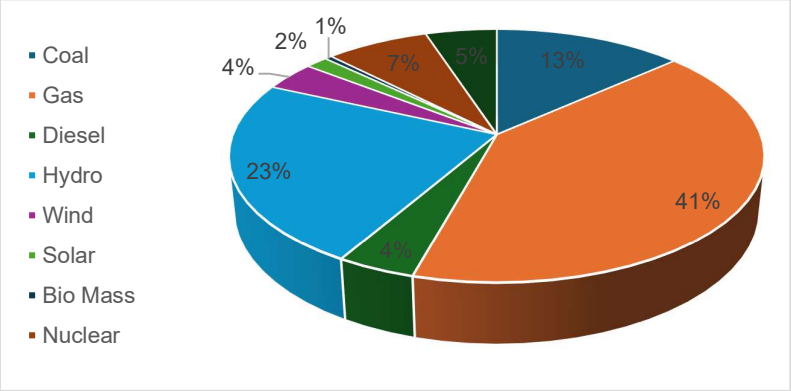


Figure 8: Pakistan's installed generation capacity by fuel (PACRA, 2025)

2.2.1.7 Sri Lanka

As of 2024, Sri Lanka's installed electricity generation capacity reached 4,117 MW. The energy mix is primarily handled by hydropower, which accounts for the largest share, followed by diesel/fuel oil and coal. Renewable sources, including hydro, wind, solar, and biomass, make up about 63% of the total capacity, indicating a strong presence of clean energy in the system. Fossil fuels still contribute over one-third of capacity, with diesel/fuel oil as the leading thermal source. According to the Ministry of Power and Energy, electricity generation in recent years has relied heavily on hydropower, especially during the monsoon season, while coal and thermal oils are used to meet demand during dry periods. The industrial and household sectors drive the bulk of electricity consumption. With energy security and import dependence posing challenges, Sri Lanka has continued to push for a greater share of renewables in its long-term energy strategy.

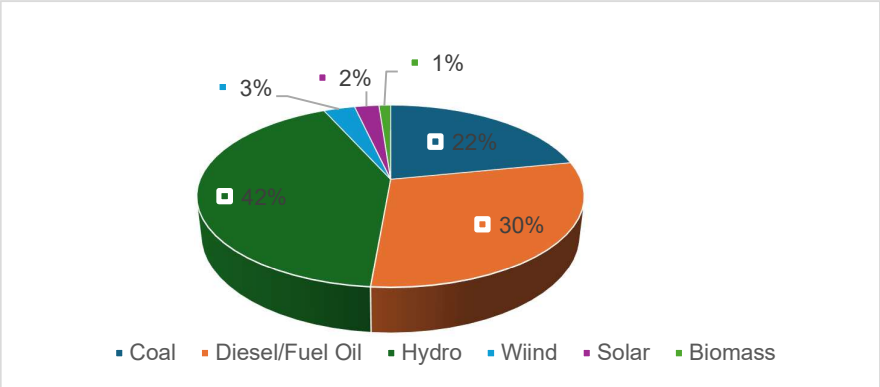


Figure 9: Sri Lanka's total generation (up to 2024) (CEB, 2025)

2.2.2 United States of America

In 2024, total energy production in the United States reached a record 103 quadrillion Btu, equivalent to approximately 30,200 TWh, marking a 1% increase from 2023 (Source: EIA, Monthly Energy Review 2024). Natural gas led the energy mix, contributing around 11,480 TWh, followed by crude oil at approximately 8,150 TWh, coal at 3,015 TWh, and natural gas plant liquids (NGPL) at 2,710 TWh. Natural gas production remained stable at 1.08 trillion cubic meters, while crude oil output increased to 2.1 billion litres per day, driven mainly by activity in the Permian Basin. Coal production dropped to 464 million metric tons, the lowest since 1964. Renewable energy sources reached new highs: biofuel production rose to 222

million litres per day (a 6% increase), solar power generation grew by 25%, and wind power expanded by 8% compared to 2023. Hydropower and geothermal sources remained relatively stable, with minor year-on-year fluctuations (The World Bank, 2025).

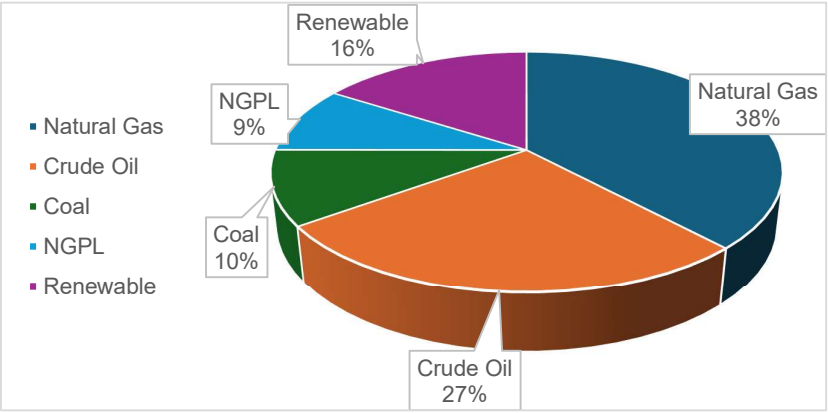


Figure 10 U.S. energy production by source,2024 (EIA, 2025)

2.2.3 China

China's energy sector is undergoing a transformative phase, highlighting renewable energy and decarbonisation. According to DNV's Energy Transition Outlook, China is responsible for 33% of the world's energy-related CO2 emissions, which is projected to reduce to 22% by 2050, achieving a reduction of up to 8 GtC02. In 2024, China's total energy production reached approximately 160,000 PJ. The energy mix consisted of coal at 50% (80,000 PJ), renewables—including hydro, wind, and solar—at 25% (40,000 PJ), oil at 15% (24,000 PJ), natural gas at 8% (12,800 PJ), and nuclear at 2% (3,200 PJ), according to estimates from the IEA and DNV.

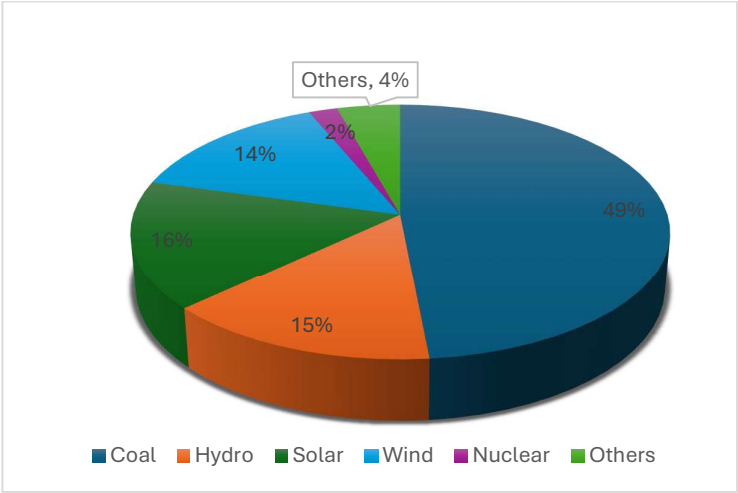


Figure 11: Energy production in China-2024 (IEA, 2022)

Installed power generation capacity totalled around 2,800 GW, distributed as follows: coal 50% (1,400 GW), hydro 15% (420 GW), solar 16.8% (470 GW), wind 14.8% (415 GW), nuclear 2% (57 GW), and other sources 4.5% (125 GW). China's CO2 emissions, which accounted for 33% of global emissions in 2023 (12.1 gigatons CO2), are projected to peak by 2026 and then decline to 22% of global totals by 2050, as outlined in DNV's Energy Transition Outlook China

2024. Renewables contributed 39% of China's electricity generation mix in 2024, up from 30% previously, with a target of reaching 88% by 2050—solar alone is expected to make up 38%. Energy demand in China is anticipated to peak around 2030 and decrease by 20% by 2050, driven by increased electrification and improvements in energy efficiency. (IRENA, 2023)

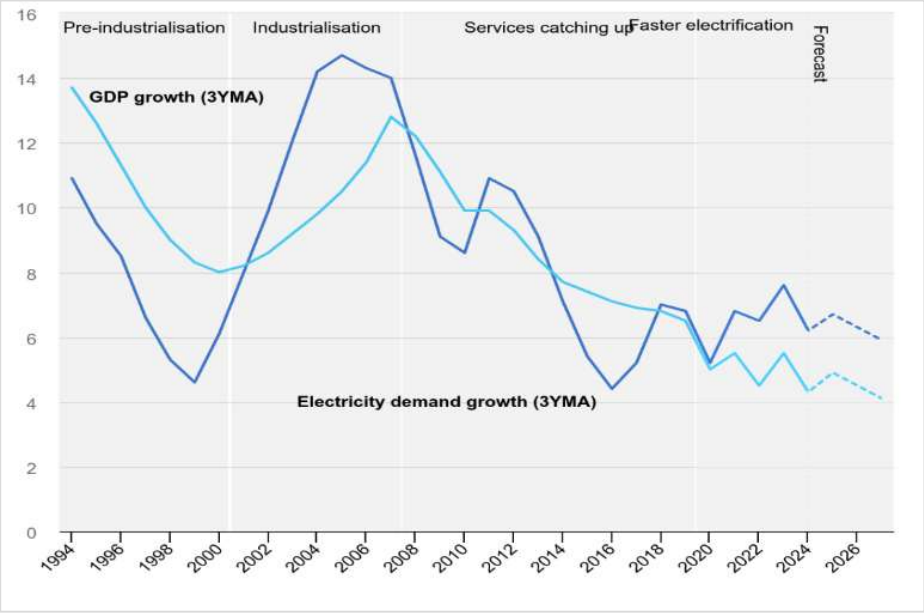


Figure 12: Growth rates of electricity demand and GDP in China,1994-2027 (IEA, 2022)

2.3 The Global Energy Scenario

The World Energy Outlook 2024 by the International Energy Agency (IEA) offers insights into the global energy landscape, highlighting trends and challenges as of June 2025. It emphasises the need for a faster shift to clean energy amid geopolitical tensions and volatile markets. In 2024, global energy demand increased by 2.2%, faster than the 1.3% average annual growth from 2013 to 2023, with emerging economies driving over 80% of this rise. Electricity demand surged by 4.3%, fueled by cooling needs, industrial growth, transport electrification, and data centres. While the exact total final energy consumption (TFC) for 2024 isn't available, historical data suggests the industry sector is the largest consumer, followed by buildings and transport, with renewables and nuclear meeting much of the new electricity demand.

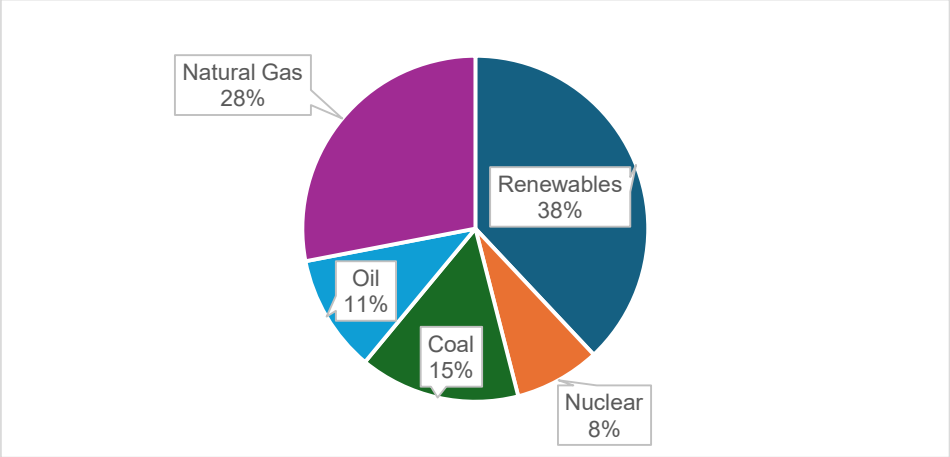


Figure 13: Global demand growth by source (WEC, 2024)

2.3.1 Energy Consumption: Trends and Sector Breakdown

Global energy demand experienced a notable increase of 2.2% in 2024, surpassing the 1.3% average annual growth observed between 2013 and 2023, as reported in the IEA's Global Energy Review 2025. This surge was predominantly driven by emerging and developing economies, which accounted for over 80% of the demand increase, despite a slowdown in China, where energy consumption rose by less than 3% compared to 2023's rate. Advanced economies also saw a return to growth, with demand increasing by nearly 1%.

The power sector led this growth, with electricity demand rising by 4.3% in 2024, a significant jump from the 2.5% growth in 2023. This acceleration was driven by several factors: increased demand for cooling due to record global temperatures, rising industrial consumption, the electrification of transport, and the expansion of data centres and artificial intelligence technologies. Globally, electricity consumption increased by 1,080 TWh, with China contributing over 550 TWh (7%) to this rise, highlighting its significant role.

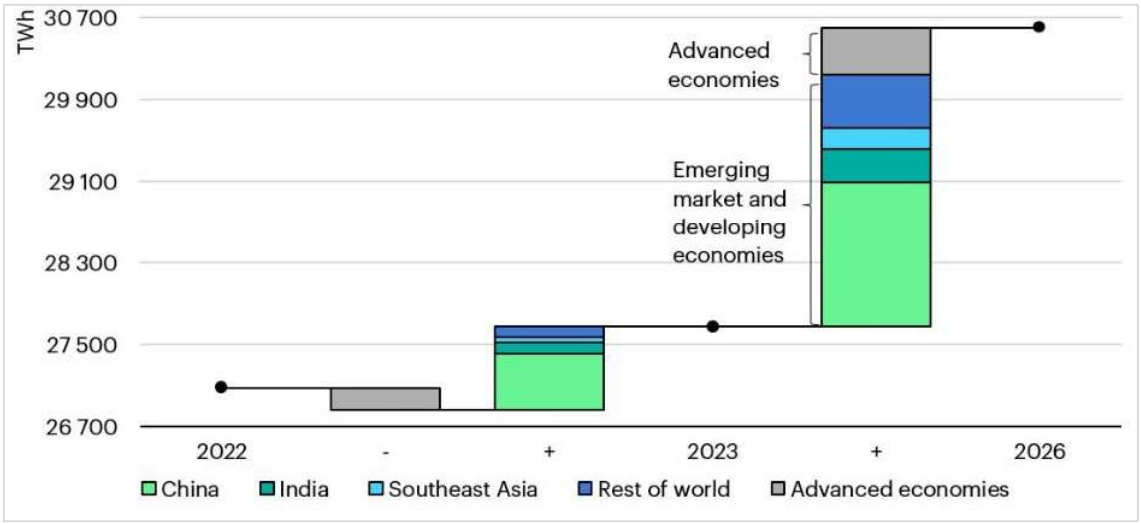


Figure 14: Global Electricity Demand by Region(2022-2026) (IEA, 2024)

While specific data on total final energy consumption (TFC) for 2024 was unspecified, historical context from earlier IEA reports suggests that the industry sector remains the largest

energy consumer, accounting for a significant share, followed by buildings and transport. The 2022 TFC was reported at 442 EJ in the 2024 synopsis, indicating a growth trend, but exact 2024 figures remain elusive.

The shift towards cleaner energy is evident, with renewables and nuclear power covering 80% of the electricity demand increase in 2024, contributing 40% of total generation for the first time, as per the IEA news release "Growth in global energy demand surged in 2024 to almost twice its recent average".

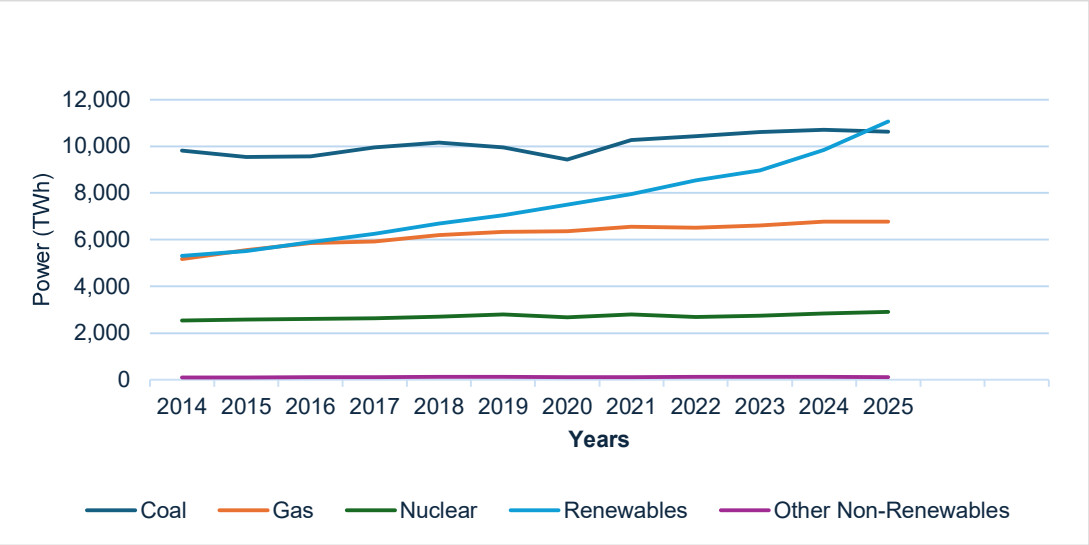


Figure 15: Global Electricity generation by source,2014 - 2025 (IEA, 2024)

2.3.2 Future Energy Scenarios and Projections

The IEA's World Energy Outlook 2024 introduces three main scenarios to project the future of energy systems and their climate impact:

Net Zero Emissions by 2050 (NZE) Scenario: This pathway aims to limit global temperature rise to 1.5°C above pre-industrial levels by 2100, with limited overshoot. It aligns with the UN Sustainable Development Goals, focusing on improving air quality and ensuring universal access to modern, sustainable energy by 2030. Achieving this scenario requires rapid decarbonization and net-zero emissions by 2050.

Announced Pledges Scenario (APS): This scenario assumes governments fulfil all climate-related commitments, including net-zero targets and Nationally Determined Contributions (NDCs), enhanced by business pledges. It projects a temperature rise of 1.7°C by 2100 but notes that most governments lack policies to fully achieve these commitments, necessitating significant progress.

Stated Policies Scenario (STEPS): Reflecting current policy landscapes, STEPS focuses on what governments are doing, not just what they pledge. It projects a 2.4°C warming by 2100, based on policies and measures in place or announced, without assuming aspirational targets will be met. This scenario highlights the gap between current actions and climate goals.

2.3.3 Industrial Policies: Global Efforts and Regional Highlights

Countries are passing targeted policies to boost clean energy manufacturing and deployment, as depicted in the WEO 2024. Recent developments include:

United States: The administration issued executive orders in January 2025 to unleash American energy, focusing on affordable and reliable resources. Additionally, the Natural Resources Committee's reconciliation bill proposes increased leasing on federal lands for energy, potentially impacting the energy mix.

European Union: Continues to enhance climate ambition with new targets, aligning with the Green Deal Industrial Plan to amplify investments in clean technology manufacturing.

China: Dominates manufacturing capacity across various technologies, with 60% of new renewables in 2023, and solar expected to exceed U.S. electricity demand by the early 2030s.

Other regions, such as Canada and India, are backing critical minerals and clean energy through support mechanisms and production-linked incentive schemes, respectively. These policies reflect a global push towards decarbonization, with Just Energy Transition Partnerships (JETP) agreements signed by countries like Indonesia, Vietnam, and Senegal to accelerate power sector decarbonization.

2.4 Nepal's Energy-Related Plans and Policies

2.4.1 Energy Development Roadmap 2081 BS

The Energy Development Roadmap (2081 BS) outlines an ambitious plan to transform the nation's energy sector by 2035. The key highlights of the roadmap are:

- Aim to increase installed electricity capacity to 28,500 MW by 2035.
- Increase per capita energy consumption to 1,500 kWh by 2035.
- Increase electricity exports to 15,000 MW by 2035.
- Expand electricity transmission infrastructure, reaching 17,446 circuit kilometres and substation capacity of 40,000 MVA.
- Reach 100% electrification.
- Increase internal electricity demand by 40,710 GWh.

Besides these key highlights, the roadmap lays out an investment plan, a hydropower development timeline, encourages an inclusive investment approach, addresses development challenges, promotes solar energy and aims to boost economic and employment impacts.

2.4.2 Nationally Determined Contributions 3.0

Nepal's NDC 3.0, submitted in May 2025 under the Paris Agreement, outlines the country's climate action roadmap up to 2035. Despite contributing negligibly to global greenhouse gas (GHG) emissions, Nepal faces significant climate vulnerability due to its mountainous terrain and socio-economic challenges. NDC 3.0 builds upon earlier commitments, aligning with Nepal's Long-term Strategy (LTS) for net-zero carbon dioxide emissions by 2045 and integrating just transition, gender equality, and inclusive development.

Mitigation Targets

- Nepal aims to reduce net GHG emissions by 17.12% by 2030 and 26.79% by 2035 from the Business-As-Usual (BAU) scenario. Key targets include:
- Expanding renewable electricity generation to 14,031 MW by 2030 and 28,500 MW by 2035, with 15% from solar, wind, and bioenergy.
- Promoting clean cooking: 2.1 million electric cookstoves and 652,770 household biogas systems by 2035.
- Increasing electric vehicle (EV) sales to 95% for private and 90% for public transport by 2035.
- Enhancing energy efficiency in industry, buildings, and transport sectors.
- These targets require an estimated USD 73.74 billion, of which 85% is conditional on international support.

Adaptation Priorities

- Nepal's adaptation priorities span eight thematic areas, including:
- Agriculture and food security (climate-resilient farms, irrigation)
- Forests and biodiversity (sustainable forest management, wildfire control)
- Water and energy (resilient infrastructure, river basin planning)
- Health and sanitation (WASH, disease surveillance)
- Urban planning, DRR, and education.
- All 753 local governments will prepare and implement Local Adaptation Plans of Action (LAPAs) by 2035.

Cross-Cutting Strategies

NDC 3.0 adopts a gender-responsive, inclusive and multi-stakeholder approach, emphasises climate finance, data systems, and capacity building, and promotes co-benefits with SDGs. Nepal intends to leverage carbon markets under Article 6 of the Paris Agreement.

2.4.3 The 16th Five-Year Plan

The 16th Five-Year Plan of Nepal serves as a comprehensive framework guiding the nation’s economic and social development for the period 2081/82 to 2085/86 B.S. Anchored in the vision of "Prosperous Nepal, Happy Nepali," the plan aims to build an inclusive, just, and sustainable economy through structural reforms, improved governance, and enhanced service delivery.

The key objectives of the five-year plan are:

- Accelerate sustainable, inclusive, and employment-oriented economic growth.
- Improve the quality of life and human capital development.
- Strengthen good governance, service delivery, and the rule of law.
- Ensure environmental sustainability and climate resilience.
- Promote infrastructure development to support economic transformation.

The plan emphasises structural transformation of the economy, moving from subsistence agriculture to a productivity-based economy led by industry, tourism, and services. Priority is placed on:

- Enhancing agricultural productivity and commercialisation.
- Promoting industrial growth through value addition and export promotion.
- Expanding renewable energy, including hydro and solar.

- Developing physical infrastructure such as roads, irrigation, and digital connectivity.
- Strengthening federalism and inter-governmental coordination.

The plan aims to improve human development indicators by investing in education, health, and social protection. Key targets include reducing poverty, enhancing skills and employment, and ensuring social inclusion of marginalised groups.

Environmental and Climate Commitments: In alignment with global commitments like the SDGs and Nepal's Nationally Determined Contributions (NDCs), the plan incorporates climate-resilient development, disaster risk reduction, and sustainable natural resource management.

Implementation Strategies: To meet its targets, the plan emphasises:

- Public-private partnerships (PPPs) for infrastructure and service delivery.
- Decentralised planning and effective service delivery through provincial and local governments.
- Fiscal reforms to enhance domestic resource mobilisation.
- Monitoring and evaluation systems to ensure results-oriented implementation.

The plan projects an average annual economic growth of 7.3%, aiming to reduce poverty below 15% by the end of the plan period. It also seeks to boost per capita income, enhance national productivity, and create over 500,000 jobs annually.

2.4.4 National Adaptation Plan (NAP) 2021-2050

Nepal's National Adaptation Plan (NAP) 2021–2050 provides a strategic framework for building climate resilience and adapting to the impacts of climate change across key sectors and vulnerable regions. Developed under the leadership of the Ministry of Forests and Environment, the NAP aims to mainstream adaptation into national development planning while ensuring an inclusive, evidence-based, and participatory approach.

The plan identifies climate change as a major threat to Nepal's socio-economic development, ecosystems, and the livelihoods of its people, particularly marginalised groups such as women, indigenous communities, and the poor. With rising temperatures, changing precipitation patterns, and increased frequency of extreme events, Nepal faces mounting risks to agriculture, water resources, biodiversity, infrastructure, and public health.

The NAP outlines 10 thematic areas (such as agriculture, forests, water, energy, health, and urban settlements) and 5 cross-cutting areas (including gender and social inclusion, governance, capacity building, and disaster risk reduction). It sets long-term adaptation goals and presents a strategic direction for each sector, supported by short-term, medium-term, and long-term priorities. These priorities are derived from rigorous vulnerability assessments and consultations with stakeholders at national and subnational levels.

Key features of the plan include:

- Adaptation Vision: Building a climate-resilient Nepal by 2050 through inclusive, green, and sustainable development.
- Implementation Strategy: Decentralised, integrated, and coordinated mechanisms involving federal, provincial, and local governments.
- Financing: Emphasis on mobilising domestic resources, climate finance (such as the Green Climate Fund), and private sector investment.
- Monitoring and Evaluation: Establishment of a robust M&E system to track progress, enhance accountability, and inform adaptive management.

- Capacity Building: Strengthening institutional, technical, and human capacities to effectively plan and implement adaptation actions.

The NAP also acknowledges the importance of linking adaptation with mitigation co-benefits, disaster risk management, and the Sustainable Development Goals (SDGs). It promotes ecosystem-based adaptation, nature-based solutions, and the use of traditional knowledge systems alongside scientific approaches.

Ultimately, the NAP serves as a comprehensive and forward-looking roadmap to ensure that Nepal's development trajectory remains resilient in the face of climate change, while safeguarding the well-being of its people and ecosystems.

2.4.5 Ministry of Energy, Water Resources, and Irrigation – White Paper 2075 BS

The White Paper issued by MoEWRI in 2018 outlines the Government of Nepal's strategic direction for the energy, water resources, and irrigation sectors. It acknowledges Nepal's immense hydropower potential—estimated at 83,000 MW, with 42,000 MW considered technically and economically viable, yet highlights that only a small fraction has been developed.

The document emphasises a transition from energy crisis to energy security. Until 2017, Nepal faced acute power shortages and long load-shedding periods. However, improvements in electricity generation, transmission, and cross-border trading—particularly with India—helped end load-shedding in urban areas. The paper sets a target of generating 3,000 MW in three years, 5,000 MW in five years, and 15,000 MW in ten years, to meet rising domestic demand and enable electricity export.

Key policy priorities include:

- Developing reservoir-based hydropower for energy security and seasonal balance.
- Promoting private sector participation and foreign investment in generation and infrastructure.
- Facilitating electricity trade through regional cooperation, especially with India and China.
- Strengthening the transmission and distribution system to reduce losses and improve reliability.
- Prioritising access to electricity for all citizens, targeting 100% electrification within five years.
- Promoting renewable energy (solar, wind, micro-hydro) in remote areas where grid expansion is unfeasible.

The White Paper also addresses institutional reforms. It proposes restructuring the Nepal Electricity Authority (NEA) to improve efficiency, transparency, and service delivery, and strengthening regulatory bodies like the Electricity Regulatory Commission. Additionally, it highlights the need to build human resources and technical expertise to support the growing energy sector.

In water resources, the paper outlines an integrated water resource management approach to ensure sustainable use of rivers for irrigation, energy, drinking water, and flood control. The irrigation strategy includes rehabilitating existing schemes, expanding irrigation coverage, and promoting modern, efficient irrigation technologies.

The White Paper sets out a vision of Nepal as a regional clean energy hub. It seeks to leverage the country's strategic location and water resources to meet internal development goals and contribute to regional energy markets.

2.4.6 Hydropower Development Policy – 2001 AD

Nepal's Hydropower Development Policy, 2001, aims to harness the country's abundant water resources to drive economic growth through sustainable hydropower development. With a potential capacity of 83,000 MW, of which 42,000 MW is financially and technically feasible, the policy seeks to address Nepal's low electricity consumption, promote industrial growth, and reduce reliance on traditional energy sources like biomass. It builds on the 1992 policy, incorporating lessons from private sector involvement and global trends to create a clear, investment-friendly framework.

The policy focuses on generating low-cost electricity, ensuring reliable and affordable electric services nationwide, linking electrification to economic activities, promoting rural electrification, and developing hydropower as an exportable commodity.

To achieve these goals, the policy emphasises extending hydropower to rural areas, encouraging private sector participation through transparent procedures, and promoting small, medium, and large-scale projects, including storage and multipurpose initiatives. It advocates for integrated water resource management, bilateral and regional cooperation for export markets, and risk-sharing between the government and private sectors to minimise project uncertainties.

The policy prioritises maximising domestic electricity demand, developing projects on a Build, Operate, Own, and Transfer (BOOT) model, and offering incentives to attract national and foreign investment. It supports large storage and multipurpose projects to optimise downstream benefits like irrigation and flood control, with government participation where necessary. Environmental protection is emphasised, promoting hydropower as an alternative to biomass, alongside measures for resettlement and mitigating environmental impacts. Rural electrification is a focus, with provisions for a Rural Electrification Fund and exemptions for small projects (up to 1 MW) from royalties and licensing requirements. The policy encourages electricity exports, particularly for projects above 100 MW, and ensures competitive licensing for domestic projects.

It outlines environmental safeguards, such as mandating minimum water releases, and provides for land acquisition and resettlement support. Investment is facilitated through tax and customs incentives, domestic capital mobilisation, and foreign exchange facilities for repatriation. Licensing is streamlined, with clear timelines and competitive bidding for larger projects. Royalties vary by project size and purpose, with export-oriented projects facing higher rates. Institutional reforms include strengthening regulatory bodies, unbundling the Nepal Electricity Authority's functions, and establishing research and training institutes to enhance expertise.

2.4.7 Renewable Energy Subsidy Policy – 2073 BS

Nepal's Renewable Energy Subsidy Policy, 2073 BS (2016), aims to enhance access to clean, reliable, and affordable renewable energy, targeting universal access by 2030. At the time, with 85% of Nepal's energy derived from traditional biomass and 28% of households lacking electricity, the policy addresses the urgent need for renewable energy technologies (RETs) like mini/micro hydropower, solar, biogas, biomass, and wind, particularly in rural areas where grid extension is impractical due to terrain and cost.

Despite Nepal's rich renewable energy potential, high initial costs and poverty limit adoption. Past efforts since the 1990s, supported by the government, development partners, and private sector, have provided electricity to 25% of the population via RETs, including 30 MW from mini/micro hydropower and 15 MWp from solar. However, challenges like over-reliance on subsidies, limited private investment, and low productive energy use persist, necessitating a policy revision to replace subsidies with credit and attract commercial investment.

The policy seeks to reduce dependence on traditional and imported energy, improve rural livelihoods, and create employment. Strategies include lowering upfront costs, maximising service delivery, mobilising commercial credit, and encouraging public-private partnerships. It prioritises cost-effective technologies, promotes research for cost reduction, and supports gender equity by reducing women's drudgery.

Subsidies cover ~40% of RET costs, with 30% from credit and 30% from private/community contributions, varying by region (Very Remote, Remote, Accessible) and technology. For mini/micro hydropower (10-1000 kW), subsidies range from Rs. 240,000-382,000 per kW, with additional support for targeted groups (e.g., women-led households, Dalits). Solar subsidies include Rs. 4,500-10,000 for home systems and up to Rs. 495,000/kW for mini-grids. Biogas subsidies range from Rs. 16,000-35,000 for domestic plants, with waste-to-energy plants eligible for up to Rs. 240,000. Biomass subsidies support metallic cookstoves (up to Rs. 20,000), while wind and hybrid systems receive up to Rs. 495,000/kW. Productive energy use subsidies (up to Rs. 1,000,000) promote enterprises.

The Alternative Energy Promotion Centre (AEPC) oversees technical support and monitoring, while the Central Renewable Energy Fund (CREF) manages subsidy and credit disbursement. Local bodies handle demand collection and monitoring. Special provisions for earthquake-affected areas offer up to 80% subsidies. The policy emphasises quality assurance, competitive pricing via reverse auctions, and grid synchronisation where feasible, aligning with Sustainable Development Goals.

2.4.8 National Energy Efficiency Strategy 2075 BS

Nepal's National Energy Efficiency Strategy, 2075 BS (2018 AD), aims to enhance energy security and access through efficient energy use, aligning with constitutional mandates and Sustainable Development Goals (SDGs). At the time when one-fourth of Nepal's population lacked modern energy access and relied heavily on imported fossil fuels, the strategy addresses high energy intensity (1.19 tons of oil equivalent per USD 1,000 GDP) and low per capita electricity consumption (190 kWh in 2074 BS). It seeks to integrate energy efficiency into the national energy framework to support economic growth and environmental sustainability.

The vision is to bolster energy security by promoting efficient energy use. The mission involves establishing robust policy, legal, and institutional frameworks for energy efficiency programs. The primary goal is to double the energy efficiency improvement rate from 0.84% annually (2000-2015) to 1.68% by 2030, reducing energy intensity and enhancing productivity.

The strategy aims to support economic growth by lowering energy intensity, reducing energy shortages, increasing access, and enhancing energy security. It seeks to create jobs through an energy efficiency market, improve environmental balance, and promote health benefits via efficient energy use.

Its key strategies include raising awareness across consumer and policymaker levels, establishing legal and institutional frameworks, developing national energy efficiency standards, reducing production energy costs, and curbing energy imports through

conservation. Implementation involves public campaigns, educational curricula integration, and sector-specific initiatives in households, industry, commerce, transport, and agriculture. It emphasises creating an energy efficiency entity, strengthening the Ministry's energy efficiency cell, and conducting research for technology development. Energy audits, performance standards, and demand-side management are prioritised to ensure cost-effective production and reduced imports.

The strategy adopts a multi-level approach (local, provincial, federal) with sector-specific measures, time-bound plans (short, mid, long-term), and stakeholder coordination. Short-term efforts focus on awareness and energy-saving equipment, mid-term on fiscal incentives, and long-term on sustainable energy use across sectors. Legal backing will initially rely on executive orders, with future amendments to energy laws. An energy efficiency entity will oversee coordination, action plan development, and monitoring.

The funding will combine government, private, and international resources, with an estimated USD 670 million annually needed by 2030 AD. Research will focus on technology development and transfer. Its monitoring will track energy intensity and SDG 7.3 progress, with annual reports on investments and savings, ensuring periodic strategy reviews for adaptability.

2.4.9 Rural Energy Policy 2006 AD

The Rural Energy Policy of Nepal, 2006, formulated by the Ministry of Environment, aims to reduce rural poverty and promote environmental conservation by ensuring access to clean, reliable, and affordable energy in rural areas. The policy's goal is to enhance rural living standards by reducing dependence on traditional energy, increasing employment, and integrating energy with socio-economic activities. Key objectives include expanding access to cost-effective, eco-friendly energy, boosting productivity, and improving health and education outcomes, particularly for women and children.

To achieve these, the policy emphasises developing renewable energy technologies like micro-hydropower, biogas, solar, and improved cookstoves, while enhancing local governance capacity and private sector involvement. A Rural Energy Fund will mobilise financial resources, and the Alternative Energy Promotion Centre will support local bodies in program implementation. Subsidies will target remote and marginalised communities, with incentives for community-managed projects and technologies like biogas plants with toilet attachments.

Specific strategies include promoting micro-hydropower (up to 1,000 kW) with community distribution, encouraging biogas research for high-altitude areas, and developing solar and wind energy where hydropower is infeasible. Improved cookstoves and water mills will enhance efficiency, while rural electrification will integrate with national grids through power purchase agreements. The policy also supports biomass gasification, briquettes, and biofuels, alongside recycling solar batteries and creating wind energy master plans.

Institutionally, the Alternative Energy Promotion Centre oversees policy formulation, technical assistance, and monitoring, while a Rural Energy Central Coordination Committee and Central Rural Energy Fund ensure coordination and funding. District and village-level funds will support local projects. Monitoring will use output-oriented indicators, and community mobilisation will drive implementation. The policy integrates rural energy with sectors like irrigation, health, and education, prioritising women's empowerment and sustainable development, with funds from greenhouse gas emission reductions reinvested into rural energy initiatives.

2.4.10 Nepal's Energy Sector Vision 2050 AD

Nepal's Energy Sector Vision 2050 outlines a roadmap to develop a sustainable, inclusive, and resilient energy system. Anchored in the principles of green growth, energy security, and equitable access, the vision aims to harness the country's vast hydropower potential while diversifying into other renewable sources to meet domestic needs and become a regional energy exporter.

By 2050, the Vision sets the target of achieving universal access to reliable, affordable, and clean energy. It envisions a fully decarbonised electricity sector powered predominantly by hydropower, complemented by solar, wind, and bioenergy. Nepal plans to generate over 30 GW of electricity by 2050, with significant portions allocated for export, helping to drive regional integration and economic growth.

The strategy focuses on energy diversification, improved transmission and distribution infrastructure, and modernised grid systems. It emphasises decentralisation through mini-grids and off-grid systems, especially in rural and remote areas. Energy efficiency is a major pillar, with goals to reduce losses in transmission and encourage efficient end-use technologies across industries, transport, and households.

The Vision strongly links energy development to climate action and socio-economic progress. It supports green industrialisation, electric mobility, and clean cooking solutions to reduce dependence on biomass and fossil fuels. The plan also prioritises gender and social inclusion, ensuring that women, marginalised groups, and vulnerable communities are active participants and beneficiaries in the energy transition.

Institutional strengthening, good governance, and regional cooperation are identified as critical enablers. The Vision calls for transparent regulatory frameworks, enhanced private sector participation, and strong public-private partnerships. It also underlines the need for capacity development, innovation, and digitalisation to improve service delivery and planning.

Financing the energy transition is another key focus. Nepal aims to mobilise domestic and international investments, including climate finance, concessional loans, and green bonds, to support long-term energy infrastructure development.

In essence, Nepal's Energy Sector Vision 2050 is a blueprint for a low-carbon, inclusive energy future that not only meets the country's domestic needs but also positions it as a clean energy hub in South Asia. The Vision integrates environmental sustainability with economic opportunity, aiming to uplift communities, empower stakeholders, and contribute to global climate goals through a resilient and people-centred energy system.

2.4.11 Nepal's Long-Term Strategy (LTS) for Net-Zero Emissions 2021 AD

Nepal's Long-Term Strategy (LTS) for Net-Zero Emissions, submitted to the UNFCCC in 2021, outlines the country's ambition to achieve net-zero greenhouse gas (GHG) emissions by 2045, with a vision of carbon negativity by 2050. Structured in four chapters—Background and Context, Net-Zero Strategy, Means of Implementation, and Investment and Finance—the LTS aligns with Nepal's Nationally Determined Contributions (NDCs) and the Paris Agreement, emphasising sustainable development, climate resilience, and socio-economic prosperity despite Nepal's minimal global emissions contribution.

The strategy sets a vision to minimise emissions through clean energy maximisation, particularly hydropower, solar, and biogas, alongside decarbonising transport, promoting sustainable agriculture, maintaining forest cover, and enhancing waste management. It presents two mitigation scenarios: With Existing Measures (WEM), relying on current policies, and With Additional Measures (WAM), incorporating ambitious interventions like green hydrogen, biofuels, and carbon capture. The WAM scenario targets carbon neutrality by 2045, leveraging Nepal's land use, land-use change, and forestry (LULUCF) sector as a carbon sink, with emissions reductions across energy, agriculture, waste, and industry.

Sectoral strategies include expanding renewable energy to 15,000 MW by 2030, with 5–10% from micro-hydro, solar, wind, and bioenergy, and promoting electric vehicles (EVs) to cover 90% of private vehicle sales by 2030. Agriculture focuses on soil health, manure, and livestock management to curb methane, while forestry aims to maintain 45% forest cover through sustainable practices. Waste management emphasises methane recovery and energy-from-waste initiatives. Adaptation elements address Nepal's vulnerability to climate impacts like floods and landslides, prioritising resilient infrastructure and community-based solutions.

Implementation hinges on policy reforms, institutional capacity building, and international cooperation. Nepal seeks climate finance, technology transfers, and capacity support to bridge funding gaps, estimated at USD 33.04 billion for NDC implementation (2021–2030). The LTS proposes a carbon tax framework, private sector engagement, and regional energy trade, with clean energy exports to offset emissions in neighbouring countries. Governance challenges, such as policy gaps and coordination, are acknowledged, with calls for robust legal frameworks and transparency.

The LTS projects' co-benefits, like improved air quality, energy security, and equity, align with SDG 7. By 2050, per capita emissions are expected to remain low (1.8 tCO2e), supporting Nepal's transition to a middle-income country while prioritising climate resilience and sustainable growth.

3 Methodology

The preparation of the energy sector synopsis for Madhesh province has been carried out in three phases as illustrated in Figure 16.

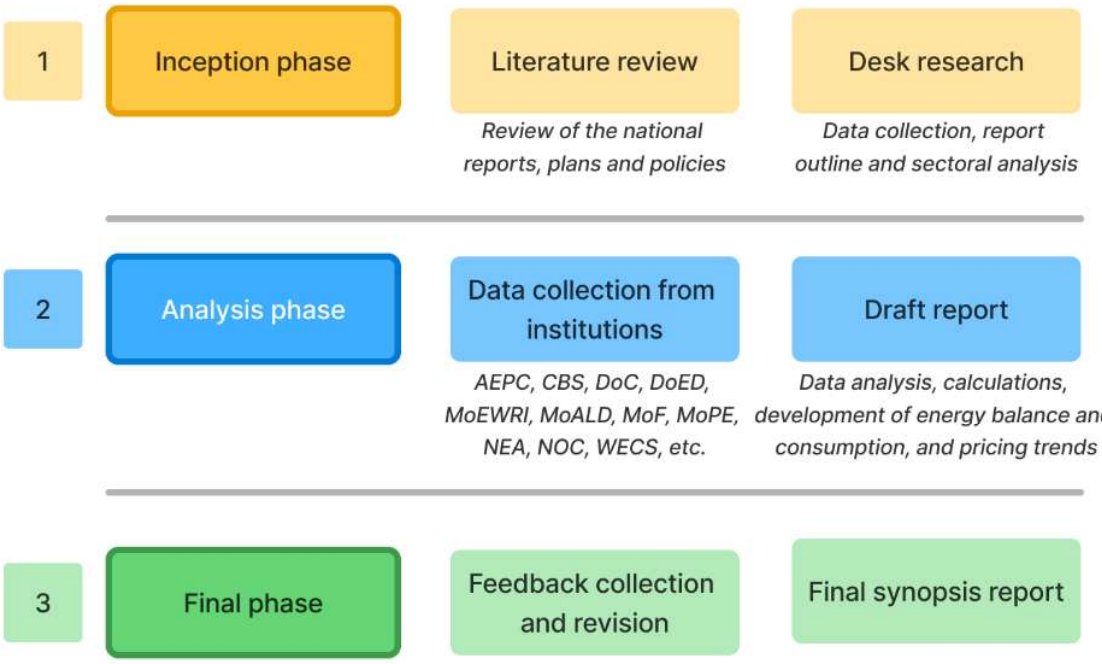


Figure 16: Methodology

In the inception phase, the overall planning for the preparation of the energy sector synopsis for Madhesh province was done. An extensive literature review was carried out, and via desk research, relevant data from credible sources were collected. The literature review included a review of WECS energy synopsis reports, Nepal's economic survey reports, Nepal's strategic plans and policy documents, and reports from relevant government institutions.

During desk research, a comprehensive analysis of the study's methodology was conducted. The workflow for preparing the synopsis report was then based on the formulated methodology derived from this analysis.

The data to be collected for the study were identified as follows:

- Supply and demand of energy sources, i.e. fuel types
  - Traditional energy sources
    - Fuelwood
    - Agricultural residue
    - Animal residue
    - Other resources, such as bagasse
  - Commercial energy sources
    - Coal
    - Petroleum oils and natural gas
    - Electricity
  - Renewable energy sources
    - Solar energy
    - Wind energy

        - Biogas
        - Other modern renewable energy sources
- Energy demand and consumption analysis
    - National demand and consumption of energy based on the aforementioned fuel types
    - Sectoral consumption analysis
        - Residential
        - Industrial
        - Commercial
        - Agriculture
        - Transportation
        - Construction and mining
- Pricing of energy

The identification of the sources of data may include, but is not limited to:

- Annual reports and other energy-related publications
- Data collection from institutions:
    - Alternative Energy Promotion Centre (AEPC)
    - National Statistics Office (NSO)
    - Department of Customs (DoC)
    - Department of Electricity Development (DoED)
    - Ministry for Energy, Water Resources, and Irrigation (MoEWRI)
    - Ministry of Agriculture and Livestock Development (MoALD)
    - Ministry of Finance (MoF)
    - Ministry of Forest and Environment (MoFE)
    - Nepal Electricity Authority (NEA)
    - Nepal Oil Corporation (NOC)
    - Water and Energy Commission Secretariat (WECS)

Table 3: Data collection from institutions

Category	Institutions
Fuelwood, agriculture and animal residue	Ministry of Agriculture and Livestock Development (MoALD)
	Ministry of Forest and Environment (MoFE)
Coal and Petroleum Products	Department of Customs (DoC)
	Nepal Oil Corporation (NOC)
Electricity	Department of Electricity Development (DoED)
	Ministry for Energy, Water Resources, and Irrigation (MoEWRI)
	Nepal Electricity Authority (NEA)
	Water and Energy Commission Secretariat (WECS)
Renewable Energy	Alternative Energy Promotion Centre (AEPC)
	Department of Electricity Development (DoED)
	Water and Energy Commission Secretariat (WECS)
Demographic and Economic Data	National Statistics Office (NSO)
	Ministry of Finance (MoF)

Identification of the data variables for the study (which encompassed, but was not restricted to, the following:

- Traditional energy sources
    - Fuelwood, agricultural residue, animal residue, and bagasse
        - Sources
        - Supply potential

- Commercial energy sources
    - Coal
        - National production
        - Imports
    - Petroleum oils and natural gas
        - Types
        - Imports
        - Sales
    - Electricity
        - National potential and production (including off-grid)
        - Import
        - Export
    - Renewable energy sources
        - Solar, wind, biogas, micro/pico hydropower
        - Total potential
        - Number of installations

3.1 Key data sources and Methodology

Traditional sources

Fuelwood, agriculture residue and animal dung data were requested from (i) Provincial Forest Directorate, Forest Corporation Madhesh Province, Forest Division Office, Janakpur, (ii) Ministry of Forest and Environment, Janakpur, Dhanusha, and (iii) Ministry of Forests and Environment, Singh Durbar, Kathmandu (see Annex). However, data for 2081/82 were not available.

Hence, data from the following reports were obtained and projected for FY 2081/82, 2082/83 and 2083/84: (i) WECS Energy Synopsis Report 2024 and (ii) Energy Consumption and Supply Situation in Federal System of Nepal (Province No. 1 and Province No. 2). The projected data was then adjusted in alignment with the NDC targets.

Commercial Energy

Data for commercial energy source is obtained from (i) Nepal Electricity Authority, (ii) Alternative Energy Promotion Centre, (iii) WECS Energy Synopsis Report 2024, (iv) Energy Consumption and Supply Situation in Federal System of Nepal (Province No. 1 and Province No. 2), (v) National Population and Housing Census 2021.

Key inputs include:

- NEA annual report (2023/2024): 2,138 GWh (20.9%) energy sales in Madhesh province out of total NEA electricity sales.
- Production of solar photovoltaic electricity in Madhesh province is 29,680 MWh.
- In 2028, an additional 8 MW solar utility plant is planned to be in operation.

Therefore, energy production and transformation (as of energy balance) remain the same till FY 2082/84, with energy from an additional 8 MW solar plant in FY 2083/84.

Similarly, petroleum data were requested from the Nepal Oil Corporation for supply and consumption of Motor Spirit, High-Speed Diesel and Superior Kerosene Oil, Liquefied Petroleum Gas, Aviation Turbine Fuel and Furnace Oil (see Annexe). Primary data was received on Madhesh province's import and sales data up to 2081/82 Baisakh for Motor Spirit, High-Speed Diesel and Superior Kerosene Oil.

Hence, data for Liquefied Petroleum Gas, Aviation Turbine Fuel and Furnace Oil were estimated based on secondary data from (i) WECS Energy Synopsis Report 2024, (ii) Energy Consumption and Supply Situation in Federal System of Nepal (Province No. 1 and Province No. 2), and (iii) National Population and Housing Census 2021.

The consumption of Liquefied Petroleum Gas (LPG) in the Madhesh province is estimated based on the population census 2021 by correlating the share (%) of households that use LPG in Nepal province to the share (%) of households in the Madhesh province.

For example,

Total LPG consumed = {per capita LPG (kg) * population}/{LPG density (kg/L) *1000}

LPG per capita consumption = 50 kg (assumed)

LPG density = 0.51 to 0.58 kg/L (assume = 0.56 kg/L)

1kg LPG = 46 MJ

Total imported LPG is then correlated to the percentage of households that use LPG in 2021 (28.70% of total national households) and proportioned to the number of households in the Madhesh province.

Similarly, the consumption of Aviation Turbine Fuel (ATF) in the Madhesh province is estimated considering the total number of flights.

For example, the average flight count to Janakpur, Simara and Rajbiraj airports

Fuel consumption = 12 to 15kg (considered 12kg per flight)

Density of ATF fuel = 0.71 kg/L

Total fuel consumption = annual fuel consumption/(density * 1000)

With ATF storage, the percentage from the national data was estimated at 10%.

Modern Renewables

Data for modern renewables is obtained from (i) Alternative Energy Promotion Centre, (ii) WECS Energy Synopsis Report 2024, and (iii) Energy Consumption and Supply Situation in Federal System of Nepal (Province No. 1 and Province No. 2).

The technologies relevant for Madhesh province are Solar Home System, Domestic Biogas, Institutional SPV, Solar Pumping, and Metallic ICS. There are no MHPs and Large Biogas in the province. Based on the AEPC annual report, the total number of plants or kW of each technology was obtained.

Assumptions:

SHS: 50Wp per installed number

ISPV: 2.5kWp per installed number

SWP: 1 to 5 kW; considered = 4kWp

PSH = 4kWh/m2/day

Biogas = 5 cubic meter per installed number [1 cum = 6.1 kWh]

Improved cooking stove = 1.5 to 2 kW; considered = 2kW

For the above input data, the projections for FY 2081/82, 2082/83 and 2083/84 were estimated, where the annual reduction in use of these energies was taken into consideration based on the NDC target.

A detailed procedure of data analysis was prepared, which involved, but was not limited to:

- Provincial supply and consumption
    - Based on fuel types
    - Based on consumption sectors

With this data collected, the outline for the draft report was prepared.

Finally, the analysis phase of the study consisted of data collection from relevant institutions, analysis of data, development of consumption and pricing trends, and preparation of a draft report. To analyse the data, interactive workshops and discussion sessions were conducted with experts and concerned authorities.

- Data collection
    - Secondary data were collected from various institutions and publications
    - Data was sorted and classified based on the categories established during the desk review phase.
- Result analysis
    - Data analysis and calculation
        - Total energy potential and supply of the energy sources
        - Total energy consumption
            - Consumption based on fuel types
            - Consumption based on sector
    - Development of the energy balance and consumption trends for fiscal years 2081/82, 2082/83 and 2083/84.
    - Analysis of pricing trends over time
    - Analysis of results against national and international goals, plans and policies.
- Preparation of draft report
    - The results from the analysis were compiled and presented in a streamlined report format. The draft report was then submitted.
- Workshop with stakeholders
    - A workshop was held with the Ministry of Energy, Irrigation and Water Supply of Madhesh province during which the results of the report were discussed.

In the final phase of the project, the feedback from the stakeholders was integrated into the draft report.

4 Energy Supply and Generation

Nepal's energy supply system is divided into three types based on the source and economy of the energy: traditional, commercial and modern renewables (see Figure 2).

4.1 Traditional Energy Resources

4.1.1 Fuelwood

Fuelwood remains a significant source of energy, particularly for cooking and heating in rural households. It is primarily sourced from local forests, private lands, and community-managed forests. The total area of Madhesh province is 966,100 ha, out of which forest covers 263,630 hectares (DFRS, 2025), Table 4, which is the source of fuelwood.

Table 4: Distribution of forest across districts and municipalities (DFRS, 2025)

District	Forest ('000 Ha)	Village municipality	Urban municipality	Sub-metropolitan city	Wildlife reserve	Total
Bara	46.63	9	4	2		15
Dhanusha	27.15	8	8	1		17
Mahottari	22.24	12	3			15
Parsa	76.23	11	1	1	1	14
Rautahat	26.29	13	3			16
Saptari	21.14	9	8			17
Sarlahi	25.77	7	10			17
Siraha	18.19	11	6			17
Total	**263.63**	**80**	**43**	**4**	**1**	**128**

About 79,157 hectares are covered by community forest (MOFE, 2020). This distribution highlights the significant role community-managed forests play in various regions across Nepal, contributing to local livelihoods and broader conservation efforts.

4.1.2 Agriculture Residue

Residues from different types of crops can be utilised as a source of energy generation. The energy generated depends on the calorific value of these residues. Among the crops such as paddy, wheat, millet, and corn contribute the largest portion. Table 5 and Table 6 present the estimated values of residues produced and the corresponding energy potential, respectively (in million tons, Table 5, and 000 GJ, Table 6).

Table 5: Total agriculture residue produced (million tons), estimated from (WECS, 2024)

Province	FY 2075/76	FY 2076/77	FY 2077/78	FY 2078/79	FY 2079/80	FY 2080/81
Koshi	2,358,762	2,385,173	2,532,781	2,599,591	2,686,601	2,773,611
Madhesh	2,241,037	2,199,426	2,339,566	2,358,539	2,407,803	2,457,067
Bagmati	1,348,355	1,366,068	1,448,861	1,488,267	1,538,520	1,588,773
Gandaki	1,044,170	1,047,836	1,109,032	1,128,671	1,161,102	1,193,533
Lumbini	2,065,559	2,104,198	2,237,234	2,307,339	2,393,176	2,479,013
Karnali	532,004	576,345	611,023	652,143	691,653	731,163
Sudurpaschim	1,053,653	1,213,755	1,289,527	1,421,519	1,539,456	1,657,393
Total	**10,643,540**	**10,892,801**	**11,568,024**	**11,956,069**	**12,418,311**	**12,880,553**

Table 6: Total energy potential from agriculture residue (000 GJ), estimated from (WECS, 2024)

Province	FY 2075/76	FY 2076/77	FY 2077/78	FY 2078/79	FY 2079/80	FY 2080/81
Koshi	89,914	91,007	96,689	99,239	102,561	105,883
Madhesh	85,276	83,835	89,169	89,892	91,770	93,648
Bagmati	51,819	52,570	55,795	57,313	59,248	61,183
Gandaki	39,369	39,485	41,850	42,591	43,815	45,039
Lumbini	79,184	80,744	85,848	88,538	91,832	95,126
Karnali	20,735	22,495	23,860	25,466	27,009	28,552
Sudurpaschim	40,179	46,440	49,344	54,395	58,908	63,421
Total	**406,476**	**416,576**	**442,555**	**457,434**	**475,143**	**492,852**

Figure 17 shows the agriculture residue energy of Madhesh province over the years. In the last three years, the average rate of increase in agriculture residue is 2%, which is less than that of animal dung.

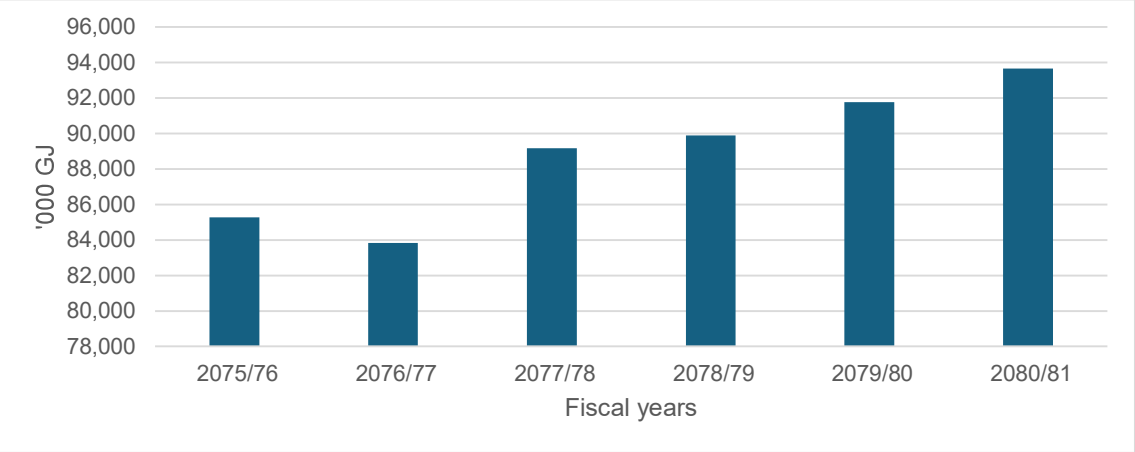


Figure 17 Agriculture residue of Madhesh province

4.1.3 Animal Dung

The potential availability of animal dung was estimated based on the populations of cattle and buffalo. As reported by WECS in 2010, the total potential supply of dry dung in 2008/09 was 15 million tons. In 2019, with a collection efficiency of 70%, approximately 6.8 million tons of dry dung were collected, corresponding to cattle and buffalo populations of 7.4 million and 6.9 million, respectively. Table 7 and

Table 8 presents the estimated dung production and the associated energy potential (in million tons,

Table 7, and 000 GJ, Table 8).

Table 7: Total animal dung produced (million tons), estimated from (WECS, 2024)

Province	FY 2075/76	FY 2076/77	FY 2077/78	FY 2078/79	FY 2079/80	FY 2080/81

Koshi	1,351,458	1,373,824	1,387,369	1,406,795	1,424,751	1,442,707
Madhesh	1,182,948	1,242,857	1,255,812	1,300,069	1,336,501	1,372,933
Bagmati	1,017,255	1,031,999	1,044,292	1,058,219	1,071,737	1,085,255
Gandaki	745,795	713,063	722,121	703,319	691,482	679,645
Lumbini	1,389,747	1,427,643	1,444,683	1,475,627	1,503,095	1,530,563
Karnali	419,649	365,390	369,565	334,784	309,742	284,700
Sudurpaschim	709,427	685,276	692,711	692,711	670,730	648,749
Total	**6,816,279**	**6,840,052**	**6,916,553**	**6,971,524**	**7,008,038**	**7,044,552**

Table 8: Total energy potential from animal dung (000 GJ), estimated from (WECS, 2024)

Province	FY 2075/76	FY 2076/77	FY 2077/78	FY 2078/79	FY 2079/80	FY 2080/81
Koshi	20,164	20,497	20,700	20,989	21,257	21,525
Madhesh	17,650	18,543	18,737	19,397	19,941	20,485
Bagmati	15,177	15,397	15,581	15,789	15,990	16,191
Gandaki	11,127	10,639	10,774	10,494	10,317	10,141
Lumbini	20,735	21,300	21,555	22,016	22,426	22,836
Karnali	6,261	5,452	5,514	4,995	4,621	4,247
Sudurpaschim	10,585	10,224	10,335	10,132	10,007	9,882
Total	**101,699**	**102,052**	**103,196**	**103,812**	**104,559**	**105,306**

Figure 18 shows the animal dung energy of Madhesh province over the years. In the last three years, the average increase rate of the animal dung energy is 9%.

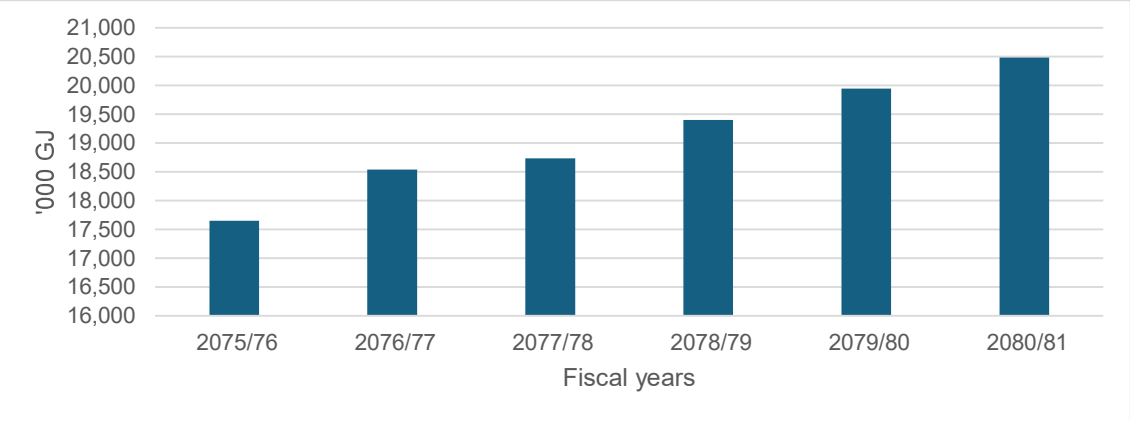


Figure 18: Animal dung of Madhesh province

4.2 Commercial Energy

4.2.1 Coal

Madhesh province does not produce coal. All coal produced in Nepal is in Lumbini province. In FY 2076/77, the country produced 7,250 tons of coal. Production increased to 11,304 tons in FY 2077/78, then fell to 6,927 tons in FY 2078/79 and 2,948 tons in FY 2079/80. By FY 2080/81, the coal production had declined to 2,623 tons, a 11% decrease from the previous year.

Table 9: Total national production of coal and total imports up to FY 2080/81 (DoC, 2025)

	FY 2075/76	FY 2076/77	FY 2077/78	FY 2078/79	FY 2079/80	FY 2080/81
National production (kg)	-	7,250,100	11,303,900	6,927,040	2,947,600	2,623,200
Import (kg)						
Anthracite, not agglomerated	3,201,287	2,982,833	110,479	96,559	245,266	837,650
Bituminous coal, not agglomerated	1,056	-	207,422	40,357,160	91,153,025	121,098,550
Other coal, not agglomerated, nes	1,664,409,818	1,337,212,825	1,911,595,559	1,740,764,608	1,180,189,198	1,416,325,589
Briquettes, ovoids and similar solid fuels manufactured from coal	28,675	79,906	176,426	60,316,200	34,797,054	457,780
Agglomerated lignite	-	2	14,000	-	-	-
Lignite, not agglomerated	-	-	-	500	-	570
Peat (including peat litter), whether or not agglomerated	-	-	-	-	245,193	1,207,097
Coke and semi-coke of coal of lignite or peat; retort carbon	213,993,422	138,907,825	89,507,340	132,821,763	76,370,270	32,038,440
Coal gas, water gas, producer gas and similar gases, not petroleum gases	326	-	-	-	-	-

Imports

Coal imports in Nepal have exhibited fluctuations. In FY 2077/78, the total import amounted to 2,001,611 tons, which declined to 1,383,000 tons in FY 2079/80 and increased to 1,571,965 tons in FY 2080/81, reflecting a dependence on coal in Nepal (Figure 19).

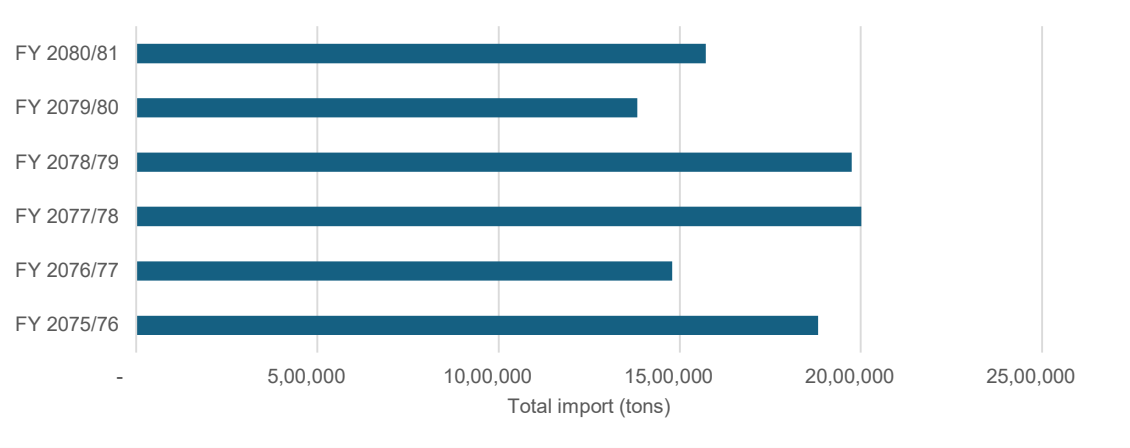


Figure 19: Total imports of coal

Madhesh Province has several coal-dependent industries, including cement plants, steel mills, and numerous brick kilns. Other industries like distilleries, paper mills, and textile factories also rely on coal-fired boilers for steam and heat, concentrated mainly in industrial hubs like Birgunj, Simara, and Bara.

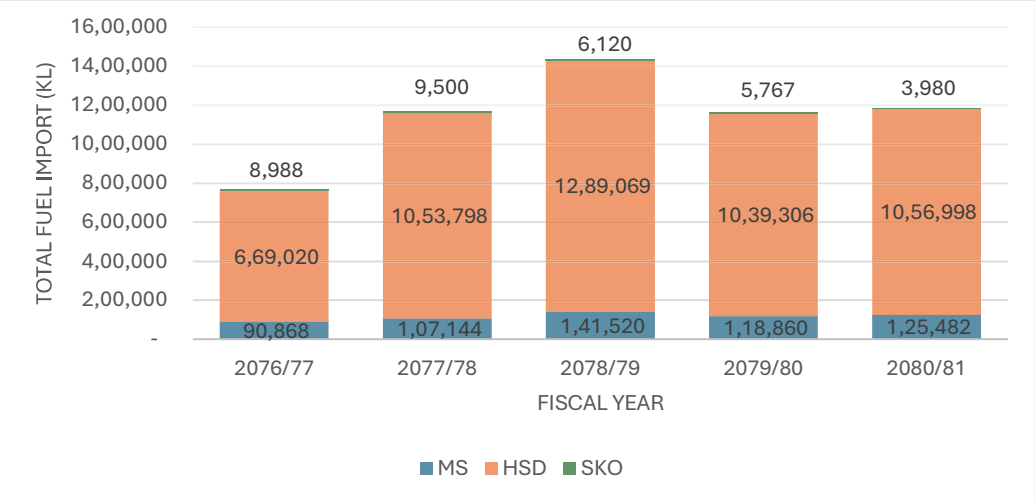
As brick being on the coal use intensive industry, out of 700 brick factories established in the eight districts of Madhesh province, only approximately 300 are currently operational. This indicates the gradual decrease in coal consumption over the years. Assuming an average brick industry consumes 374 tons of coal annually (ICIMOD, 2019), 300 brick industries consume approximately 112,250 tons of coal annually in Madhesh province. With technological advancement and energy efficiency measures, the consumption of coal across industries is expected to gradually decline.

4.2.2 Petroleum Oils and Natural Gas

Nepal imports its petroleum products primarily through its border with India. Analysing the trend of recent years, the import of petrol and diesel peaked in 2078/79 at 141,520 kL and 1,289,069 kL and has since declined in 2080/81, reaching 125,482 kL and 1,056,998 kL for petrol and diesel respectively. As for kerosene import, it has been continuously decreasing since 2077/78.

The majority of petroleum imported consists of diesel, which is consumed in the transportation, industrial, agricultural, commercial sectors, and infrastructure projects.

Import

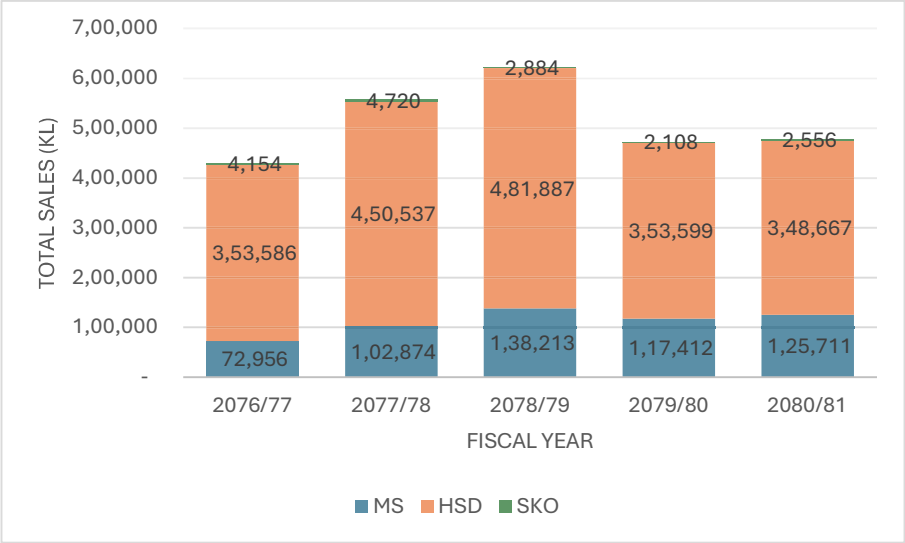


MS means Motor Spirit, HSD means High-Speed Diesel and SKO means Superior Kerosene Oil

Figure 20: Import data of petroleum fuel up to FY 2080/81, source: NOC

Figure 20 shows the annual imports of petroleum fuel across Madhesh province for the fiscal years 2076/77 to 2080/81. Each bar represents the total petroleum products imported in a specific year. The total import peaked in FY 2078/79 at 1,436,709 kL and decreased in FY 2080/81 to 1,186,460 kL.

Sales



MS means Motor Spirit, HSD means High-Speed Diesel and SKO means Superior Kerosene Oil

Figure 21: Sales of petroleum fuel in provinces up to FY 2080/81, source: NOC

Figure 21 represents the sales trend of petroleum fuel in Madhesh province. Each bar represents the total sale of petroleum products in a specific fiscal year. The maximum sale of petrol is in FY 2078/79 at 138,213 kL, and the minimum is 72,956 kL in FY 2076/77. The sales trend of diesel shows that the maximum sale is in FY 2078/79 at 481,887 kL, and the minimum is 348,667 kL in FY 2080/81. The highest sales of kerosene occurred in FY 2077/78 at 4,720 kL, and the lowest was in FY 2079/80 at 2,108 kL. Overall sales value has fluctuated in recent fiscal years.

4.2.3 Electricity

According to the Assessment of Hydropower Potential of Nepal (WECS, 2019), the hydropower potential of Madhesh province is 275 MW, which is only 0.4% of the national basin potential, i.e. 72,544 MW (WECS, 2024). Hence, there are no hydropower plants in Madhesh province.

Nepal Electricity Authority serves 1,148,674 consumers in Madhesh province from its Madhesh Provincial Office in Janakpur (NEA, 2024). The majority of the consumers, about 86.8%, are domestic consumers. Madhesh province has recorded the connected load of 489 MVA in the FY 2023/24. The annual energy sales were 2,138 GWh in the same period, which is an increase of 5.96% from the previous year. Madhesh province contributes 20.9% of the total energy sales of NEA (NEA, 2024).

While there are no hydropower plants in the province, utility-scale solar plants are being established. A total of 2,140 MW of utility-scale solar plants (from 123 projects) are in various stages of development (Table 10), while 28 MW (from 6 projects) are already operational.

Similarly, there is a 6 MW cogeneration plant (from two projects). There are no utility-scale wind power plants.

Table 10: Status of solar energy projects in Madhesh province (as of 16 May 2025 (DoED, 2025)

	No. of projects	Total capacity (MW)
Application for survey license	12	367
Survey license	93	1638.4
Application for construction license	10	62.6
Construction license	8	72
Total	**123**	**2,140**

Operational projects	6 projects 1. Mithila Solar PV Power Project, Dhanusha (10 MW) 2. Chandranigahpur Solar Project, Rautahat (4 MW) 3. Grid-Connected Solar Power Project, Dhalkebar, Dhanusha (3 MW) 4. Solar Power Project, Dhalkebar, Dhanusha (1 MW) 5. Jira Bhawani Sedawa PV Project, Parsa (7.7 MW) 6. DDB Saurya Vidyut Aayojana, Parsa (2.3 MW)	28

4.3 Modern Renewables

In terms of modern renewables, solar pumping systems make up the majority amongst other technologies installed in the Madhesh province, which is also the highest compared to other provinces of Nepal. This is followed by domestic biogas and improved metallic cookstoves in terms of the number of systems installed. The number of solar home systems and institutional solar power systems in FY 2080/81 BS is minor, which could be correlated to the result of full electrification in the province.

Table 11: Modern renewables installed in Madhesh province in FY 2080/81 (AEPC, 2024)

	Solar home systems	Domestic biogas	Metallic improved cookstoves	Institutional solar power systems	Solar pumping systems
Bara	16	13	0	0	14
Dhanusha	0	1	0	0	3
Mahottari	0	1	0	5	16
Parsa	0	9	0	1	25
Rautahat	0	59	0	0	33
Saptari	0	5	0	0	10
Sarlahi	0	47	0	2	55
Siraha	0	1	40	1	3
Total	**16**	**136**	**40**	**9**	**159**

*No micro-hydro, solar mini-grid, large biogas and electric cooking promoted in Madhesh province by AEPC in FY 2080/81 BS.

Figure 22 shows the solar energy potential of Madhesh province excluding protected areas, extreme topography (slope > 30% in mountain areas); certain land-cover classes, including closed forests, wetlands, moss and lichen, snow and ice, and water (permanent water bodies); and additional restriction that excludes areas ≤ 10 km from existing transmission lines. The potential area for utility-scale solar photovoltaic is 5,988.6 km^2 with a total solar potential of 149.7 GW (the highest potential compared to other provinces, 35% of Nepal's total solar potential under the above-described conditions, i.e. 431.8 GW) (Teske, Niklas, & Miyake, 2023).

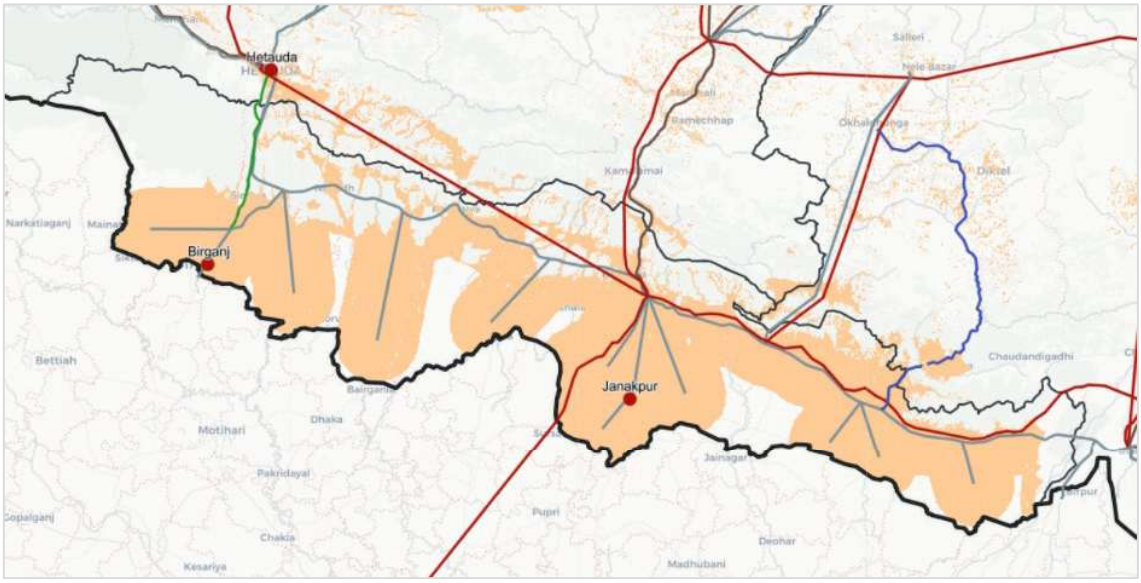


Figure 22: Solar energy potential area of Madhesh province (Teske, Niklas, & Miyake, 2023)

Similarly, Figure 23 shows the wind energy potential of Madhesh province restricted by average annual wind speed of ≥ 5 m/s, protected areas, topography (slope > 30% in mountain areas), and existing land use, including forests and urban areas; with the additional restriction excluding areas ≤ 10 km from existing transmission lines. The potential area for utility-scale wind power is 0.4 km^2 with a total solar potential of 1.9 MW (the lowest potential compared to other provinces, 0.8% of Nepal's total wind potential under the above-described conditions, i.e. 246.9 MW) (Teske, Niklas, & Miyake, 2023).

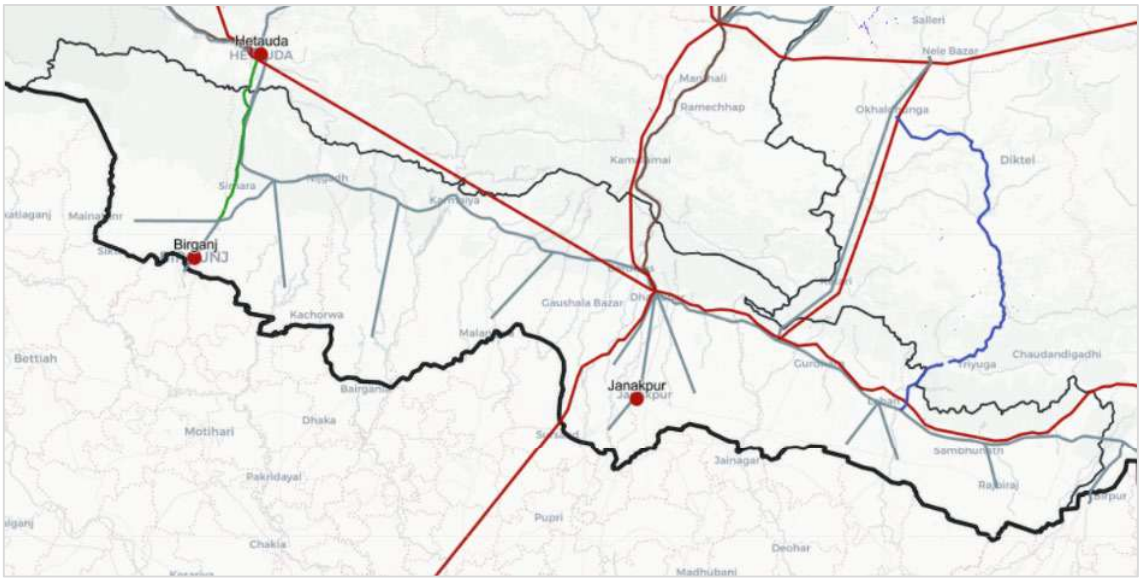


Figure 23: Solar energy potential area of Madhesh province (Teske, Niklas, & Miyake, 2023)

5 Energy Consumption

The total national energy consumption for FY 2079/80 is 532.4 PJ (WECS, 2024), Figure 24. The highest share of energy consumption is via traditional fuels at 63.9%. Similarly, commercial fuels make up 25.8%, followed by grid electricity, 7.23%, and renewables, 3.1%.

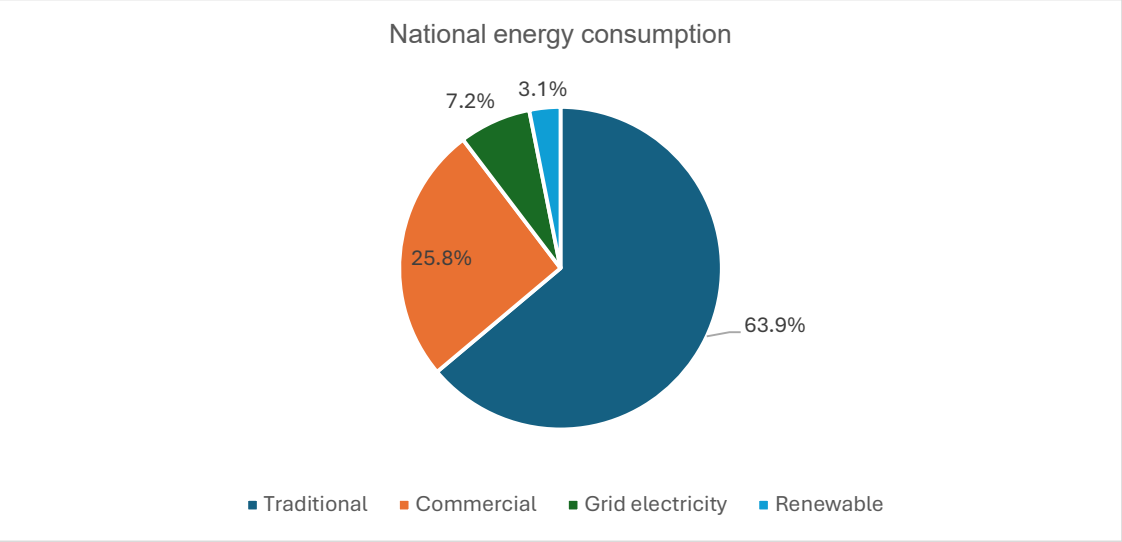


Figure 24: Energy consumption for FY 2079/80 by fuel type (WECS, 2024)

Table 12 shows the trend of energy consumption of Madhesh province from FY 2075/76 to FY 2083/84, categorised by energy sources in GJ. Biomass continues the dominate the energy consumption of the province, in which fuelwood remains the majority. However, the year-on-year trend of biomass shows a declining trend. Similarly, fuels such as coal, diesel, kerosene and furnace oil also show a declining trend. On the other hand, the trend of electricity use is increasing. This indicates a gradual shift of energy from traditional fuels & fossil fuels to clean electricity (majority hydro electricity in Nepal) and modern renewables. This positively indicates Madhesh province's transition to a sustainable source of energy with higher efficiencies.

Table 12: Trend of energy consumption of Madhesh province in 000 GJ

		2075/76	2076/77	2077/78	2078/79	2079/80	2080/81*	2081/82*	2082/83*	2083/84*
Traditional	Wood	365,089	366,847	377,790	374,563	304,625	279,159	242,576	205,993	169,410
	Agriculture Residue	18,045	18,254	18,782	17,966	25,623	24,194	25,681	27,168	28,654
	Animal Dung	18,841	17,878	17,967	18,150	9,791	11,177	9,395	7,612	5,830
Commercial	Coal	40,780	43,203	58,446	58,148	34,016	41,469	38,679	35,889	33,099
	Petroleum Products	18,735	14,473	19,561	24,654	21,932	24,420	25,606	26,792	27,977
	Diesel	63,605	41,104	63,465	66,080	49,728	46,019	39,151	32,282	25,413
	Kerosene	890	682	831	641	472	440	352	264	177
	LPG	19,606	20,493	21,803	24,657	23,677	25,759	26,999	28,240	29,480
	ATF	6,306	4,370	2,218	5,393	6,191	8,573	10,560	12,546	14,532
	Furnace Oil	1,222	374	3,399	1,834	1,369	822	522	331	210
	Electricity	22,864	23,200	26,373	31,766	38,495	40,489	44,472	48,454	52,437
	Biogas	8,175	10,141	9,757	10,489	10,722	11,678	12,146	12,614	13,082
	Wind	1.04	1.42	1.87	1.87	20	38	57	75	93
	Micro/Pico Hydro	326	436	515	540	575	659	719	780	840
	Solar	4,080	4,080	4,760	5,083	5,182	5,599	5,920	6,241	6,561
Total		**588,565**	**565,537**	**625,670**	**639,966**	**532,418**	**424,870**	**520,496**	**482,832**	**445,279**

*Consumption trends for years 2080/81, 2081/82, 2082/83 and 2083/84 are projections.

6 Energy Balance

The energy balance for Fiscal Year (FY) 2081/82, 2082/83 and 2083/84 (Table 15, Table 16 and Table 17) shows a comprehensive quantitative snapshot of the province's energy landscape. It details the flow of energy from its primary sources through transformation processes to its final consumption across various sectors. It serves as a critical tool for understanding Madhesh Province's energy dependencies, identifying areas of inefficiency, and pinpointing strategic opportunities for intervention.

Primary Energy Supply

The total primary energy supply for Madhesh Province in FY 2081/82 amounted to a substantial 95,408 TJ. This supply is a blend of domestic production, primarily from significant imports of fossil fuels and biomass.

In FY 2081/82, electricity from the utility contributed 8,232 TJ. This figure reflects the energy derived from the province's limited internal generation capacity and its share from the national grid. Madhesh Province’s low provincial generation capacity underscores a heavy reliance on external supply for its electricity needs. Biomass production, a cornerstone of traditional energy, collectively provided 34,249 TJ. Within this category, fuelwood was the dominant component, accounting for 20,455 TJ, followed by agricultural residues at 7,186 TJ and animal dung at 6,608 TJ. This highlights the continued significance of traditional biomass as a primary energy source, particularly in rural households. Modern renewables, specifically wind, showed a nascent contribution of 1.52 TJ.

In FY 2081/82, on the import front, Madhesh Province's energy security is heavily influenced by external sources. Total petroleum products imported reached 47,117 TJ. Diesel was the largest imported petroleum fuel at 38,741 TJ, followed by petrol at 4,456 TJ and LPG at 3,846 TJ. Nepal, lacking domestic oil, gas, or coal reserves, is entirely dependent on imported petroleum products, predominantly from India. Coal imports further augmented the primary energy supply by 5,808 TJ.

Based on the primary energy supply of FY 2081/82 and previous energy trends, the primary energy supply of FY 2082/83 and 2083/84 was projected. The trend of the total primary energy supply from FY 2081/82 to 2083/84 is shown in Figure 25.

Overall, the energy balance from FY 2081/82 to 2083/84 is reduced in fossil sectors (fuelwood, agriculture residue, animal dung, coal, petrol, diesel, kerosene and LPG), whereas, there is increase in the renewable energy sectors and steady with electricity, in alignment with NDC targets.

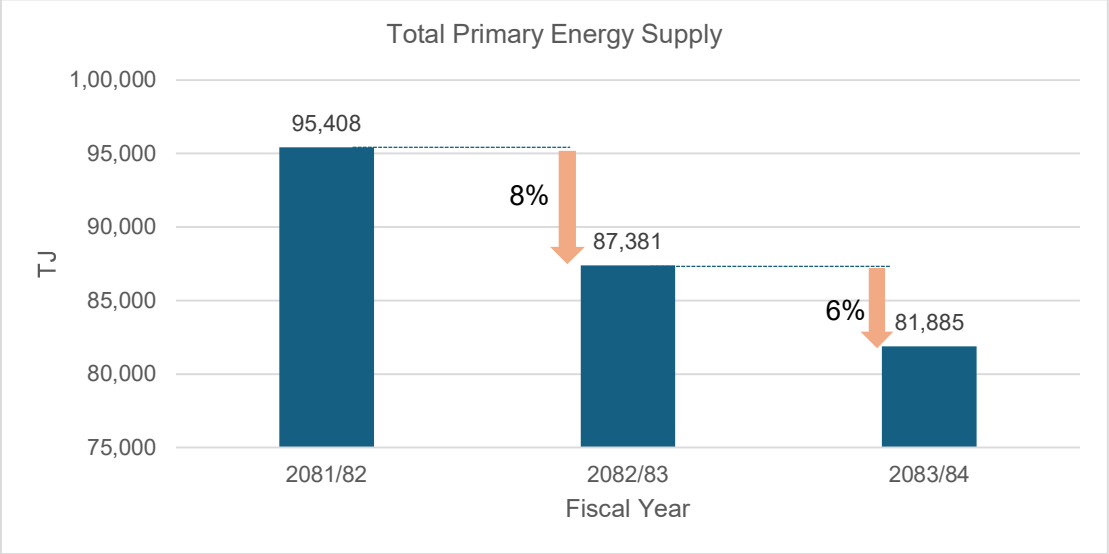


Figure 25: Trend of total primary energy supply from FY 2081/82 to 2083/84

Table 13 shows the fuel-wise percentage change from FY 2081/82 to 2083/84. The decrease in primary energy supply is from coal and biomass, whereas modern renewables are expected to increase.

Table 13: Percentage change of total primary energy supply from FY 2081/82 to 2083/84

Total Primary Energy Supply	**2081/82 (TJ)**	% change*	**2082/83 (TJ)**	% change*	**2083/84 (TJ)**
Petroleum products	47,117	5% (dec)	44,655	5% (dec)	42,231
Coal	5,808	11% (dec)	5,144	13% (dec)	4,480
Electricity	8,232	5% (inc)	8,662	5% (inc)	9,091
Biomass	34,249	16% (dec)	28,918	10% (dec)	26,081
Modern Renewables	1.52	29% (inc)	1.96	23% (inc)	2.40

*dec means decrease, inc means increase

Transformation

The transformation section of the energy balance table shows the processes by which primary energy is converted into more usable forms, and critically, the losses incurred during these conversions.

For electricity, in FY 2081/82, a total of 67,505 TJ was consumed in transformation. A particularly striking figure is the substantial import and sales loss of diesel at 12,569 TJ. This represents a significant portion of the total energy supply that is lost before it can reach end-users, indicating considerable inefficiencies in the distribution chain or discrepancies in the distribution data. This underscores a pressing need for strategic investments in upgrading and modernising the distribution chain to minimise losses and ensure more efficient utilisation of available energy resources.

Final Consumption (Demand)

The total energy demand for Madhesh Province in FY 2081/82 was 284,186 TJ. The breakdown of this demand across various sectors reveals distinct consumption patterns and dependencies.

The residential sector emerged as the largest energy consumer, accounting for a staggering 75% of the total consumption at 213,367 TJ. This consumption is overwhelmingly dominated by biomass, with fuelwood alone comprising 199,240 TJ. Animal dung (6,402 TJ) and agricultural residue (2,498 TJ) also contributed significantly to residential biomass consumption. While there has been a notable decrease in wood and animal dung consumption over recent fiscal years, suggesting a partial shift, the continued high overall share of biomass indicates that the transition to cleaner cooking fuels is still a major challenge. This perpetuates environmental degradation, including deforestation, and contributes to severe indoor air pollution, leading to adverse health outcomes. The residential sector also consumed 2,675 TJ of petroleum products, primarily Liquefied Petroleum Gas (LPG) at 2,655 TJ.

The transportation sector heavily relies on petroleum products, consuming 11,349 TJ. Diesel accounted for a significant portion at 7,702 TJ, followed by petrol (3,646 TJ). This sector's near-total dependence on imported fossil fuels directly substantiates the report's assertion that reliance on imported fossil fuels poses a significant threat to energy security. This dependency drains foreign currency reserves, exposes the provincial economy to volatile global energy prices, and creates vulnerabilities to supply chain disruptions.

The industrial sector consumed 3,593 TJ of petroleum products. Similarly, the agriculture sector primarily utilised petroleum products (977 TJ). The commercial sector primarily consumed 13,525 TJ of biomass.

Based on the energy demand of FY 2081/82 and previous energy trends, the primary energy supply of FY 2082/83 and 2083/84 was projected. The trend of the total energy demand from FY 2081/82 to 2083/84 is shown in Figure 26.

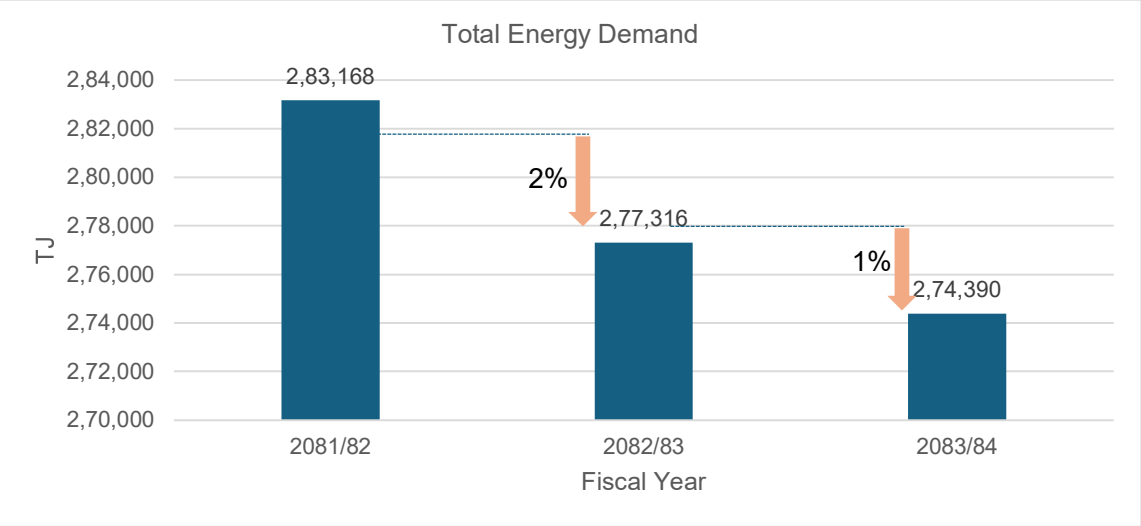


Figure 26: Trend of total energy demand from FY 2081/82 to 2083/84

Table 14 shows the fuel-wise percentage change from FY 2081/82 to 2083/84. The decrease in energy demand is from coal, whereas modern renewables are expected to increase.

Table 14: Percentage change of total energy demand from FY 2081/82 to 2083/84

Total Energy Demand	**2081/82 (TJ)**	% change*	**2082/83 (TJ)**	% change*	**2083/84 (TJ)**
Petroleum products	20,308	4% (dec)	19,416	5% (dec)	18,410
Coal	5,808	11% (dec)	5,144	13% (dec)	4,480
Electricity	7,106	5% (inc)	7,478	5% (inc)	7,849
Biomass	251,023	2% (dec)	246,814	1% (dec)	245,100
Renewables	2.40	28% (inc)	3.09	22% (inc)	3.77

*dec means decrease, inc means increase

The energy consumption of Madhesh Province remains heavily skewed towards traditional biomass for residential needs and imported fossil fuels for transportation. The significant distribution losses of diesel further highlight the need for supply chain improvements. Madhesh Province's robust pipeline of utility-scale solar projects and immense bioenergy potential from agricultural residues present crucial opportunities for diversifying its energy mix, enhancing local energy security, and fostering sustainable economic development. The data underscores the imperative for targeted policy implementation and investment to bridge the gap between ambitious national energy goals and current consumption realities.

Table 15: Energy balance of Madhesh province for FY 2081/82

TJ	Petroleum products							Coal	Electricity			Biomass				Renewables						Grand Total
	Petrol	Diesel	Kerosene	Av. Fuel	LPG	Other Petro	Total Petroleum Products	Coal	Thermal	Electricity	Total Electricity	Fuel wood	Agri. Residue	Animal dung	Total Biomass	Biogas	Micro hydro	Solar	Wind	Others	Total	
	OILGSL	OILDSL	OILKER	OILATF	OILLPG	OILOPP		SUPCOA		ELC		BIOBWD	BIOBAR	BIOBAD		BIOBGS	RNWMHD	RNWSOL	RNWWIN	RNWOTR		
Primary Energy Supply																						
Production							0			107	107	20,455	7,186	6,608	34,249	0.06	0	0.97	0	0.49	1.52	34,358
Imports	4,456	38,741	74	0.86	3,846	0	47,117	5,808		8,125	8,125				0						0	61,050
Exports							0				0				0						0	0
Stock changes							0				0				0						0	0
Total Primary Energy Supply	4,456	38,741	74	0.86	3,846	0	47,117	5,808	0	8,232	8,232	20,455	7,186	6,608	34,249	0.06		0.97	0	0.49	1.52	95,408
Statistical Difference	-14						-14			-29	-29										-0.01	-43
Transformation																						
Inputs							0				0				0						0	0
Electricity generation							0				0				0	0.06	0	0.82	0		0.88	1
T & D losses	-216	-26,172	12	-0.85	-387	0	-26,764			-1,097	-1,097				0						0	-27,860
Other losses, own-use etc.							0				0				0						0	0
Net Supply to Consumers	4,227	12,569	86	0.01	3,458	0	20,340	5,808	0	7,106	7,106	20,455	7,186	6,608	34,249	0.13	0	1.79	0	0.49	2.40	67,505
Final Consumption (Demand)																						
Industry	484	2,944	54		112		3,593	5,740		2,376	2,376	24,704	4,582		29,286						0	40,996
Residential			20		2,655		2,675	1		2,979	2,979	199,240	2,498	6,402	208,141	0.13		0.76		0.35	1.24	213,796
Commercial	34		9		645		687	6		490	490	13,213	106	206	13,525			1.02		0.14	1.16	14,709
Transport	3,646	7,702		0.01	0.35		11,349			4	4				0						0	11,353
Agriculture	12	965					977			210	210				0			0.01			0.01	1,187
Others	64	958			5		1,026			1,047	1,047	71			71						0	2,144
Total Energy Demand	**4,240**	**12,569**	**86**	**0.01**	**3,458**	**0**	**20,308**	**5,808**	**0**	**7,106**	**7,106**	**235,955**	**7,186**	**6,608**	**251,023**	**0.13**	**0**	**1.79**	**0**	**0.49**	**2.40**	**284,186**

Table 16: Energy balance of Madhesh province for FY 2082/83

TJ	Petroleum products							Coal	Electricity			Biomass				Renewables						
	Petrol	Diesel	Kerosene	Av. Fuel	LPG	Other Petro	Total Petroleum Products	Coal	Thermal	Electricity	Total Electricity	Fuel wood	Agri. Residue	Animal dung	Total Biomass	Biogas	Micro hydro	Solar	Wind	Others	Total	Grand Total
	OILGSL	OILDSL	OILKER	OILATF	OILLPG	OILOPP		SUPCOA		ELC		BIOBWD	BIOBAR	BIOBAD		BIOBGS	RNWMHD	RNWSOL	RNWWIN	RNWOTR		
Primary Energy Supply																						
Production							0			107	107	19,333	4,192	5,393	28,918	0.07	0	1.25	0	0.65	2	29,027
Imports	4,207	36,575	70	0.88	3,803	0	44,655	5,144		8,555	8,555				0						0	58,355
Exports							0				0				0						0	0
Stock changes							0				0				0						0	0
Total Primary Energy Supply	4,207	36,575	70	0.88	3,803	0	44,655	5,144	0	8,662	8,662	19,333	4,192	5,393	28,918	0.07	0	1.25	0	0.65	2	87,381
Statistical Difference	-14						-14			-29	-29										-0.01	-43
Transformation																						
Inputs							0				0				0						0	0
Electricity generation							0				0				0	0.07	0	1.06	0		1	1.13
T & D losses	61	-24,876	26	-0.87	-404	0	-25,194			-1,155	-1,155				0						0	-26,349
Other losses, own-use etc.							0				0				0						0	0
Net Supply to Consumers	4,254	11,698	96	0.01	3,400	0	19,447	5,144	0	7,478	7,478	19,333	4,192	5,393	28,918	0.14	0	2.30	0	0.65	3	60,990
Final Consumption (Demand)																						
Industry	487	2,740	60		110		3,396	5,084		2,501	2,501	24,704	2,673		27,377						0	38,359
Residential			22		2,610		2,632	1		3,135	3,135	199,240	1,457	5,225	205,923	0.14		0.97		0.47	1.58	211,692
Commercial	34		10		634		677	5		515	515	13,213	62	168	13,443			1.32		0.18	1.50	14,643
Transport	3,670	7,169		0.01	0.34		10,839			4	4				0						0	10,843
Agriculture	12	898					910			221	221				0			0.01			0.01	1,131
Others	64	891			5		960			1,102	1,102	71			71						0	2,133
Total Energy Demand	**4,267**	**11,698**	**96**	**0.01**	**3,400**	**0.00**	**19,416**	**5,144**	**0**	**7,478**	**7,478**	**235,955**	**4,192**	**5,393**	**246,814**	**0.14**	**0**	**2.30**	**0**	**0.65**	**3**	**278,801**

Table 17: Energy balance of Madhesh province for FY 2083/84

TJ	Petroleum products							Coal	Electricity			Biomass				Renewables						
	Petrol	Diesel	Kerosene	Av. Fuel	LPG	Other Petro	Total Petroleum Products	Coal	Thermal	Electricity	Total Electricity	Fuel wood	Agri. Residue	Animal dung	Total Biomass	Biogas	Micro hydro	Solar	Wind	Others	Total	Grand Total
	OILGSL	OILDSL	OILKER	OILATF	OILLPG	OILOPP		SUPCOA		ELC		BIOBWD	BIOBAR	BIOBAD		BIOBGS	RNWMHD	RNWSOL	RNWWIN	RNWOTR		
Primary Energy Supply																						
Production							0			107	107	18,210	3,692	4,178	26,081	0.07	0	1.53	0	0.80	2.40	26,190
Imports	3,968	34,500	66	0.90	3,696	0	42,231	4,480		8,984	8,984				0						0	55,695
Exports							0				0				0						0	0
Stock changes							0				0				0						0	0
Total Primary Energy Supply	3,968	34,500	66	0.90	3,696	0	42,231	4,480	0	9,091	9,091	18,210	3,692	4,178	26,081	0.07	0	1.53	0	0.80	2.40	81,885
Statistical Difference	-14						-14			-29	-29										-0.01	-43
Transformation																						
Inputs							0				0				0						0	0
Electricity generation							0				0				0	0.07	0	1.30	0		1.37	1.37
T & D losses	57	-23,466	24	-1	-392	0	-23,777			-1,213	-1,213				0						0	-24,990
Other losses, own-use etc.							0				0				0						0	0
Net Supply to Consumers	4,012	11,035	90	0.01	3,303	0	18,440	4,480	0	7,849	7,849	18,210	3,692	4,178	26,081	0.14	0	2.82	0	0.80	4	56,854
Final Consumption (Demand)																						
Industry	459	2,584	57		107		3,207	4,428		2,625	2,625	24,704	2,354		27,059						0	37,319
Residential			21		2,536		2,557	0		3,290	3,290	199,240	1,284	4,048	204,572	0.14		1.19		0.58	1.92	210,422
Commercial	32		9		616		657	5		541	541	13,213	54	130	13,398			1.61		0.23	1.84	14,602
Transport	3,462	6,762		0.01	0.33		10,224			5	5				0						0	10,229
Agriculture	11	847					859			232	232				0			0.01			0.01	1,090
Others	61	841			4		906			1,156	1,156	71			71						0	2,133
Total Energy Demand	**4,025**	**11,035**	**90**	**0**	**3,303**	**0**	**18,410**	**4,480**	**0**	**7,849**	**7,849**	**235,955**	**3,692**	**4,178**	**245,100**	**0.14**	**0**	**2.82**	**0**	**0.80**	**4**	**275,795**

7 Energy Intensity

The per capita energy consumption of Madhesh province from FY 2081/82 to 2083/84 is shown in Figure 27. The per capita energy consumption in 2081/82 is 312 kWh which will gradually increase to 336 kWh by 2083/84.

For reference, the national average per capita energy consumption was 370 kWh in 2079/80 (WECS, 2024).

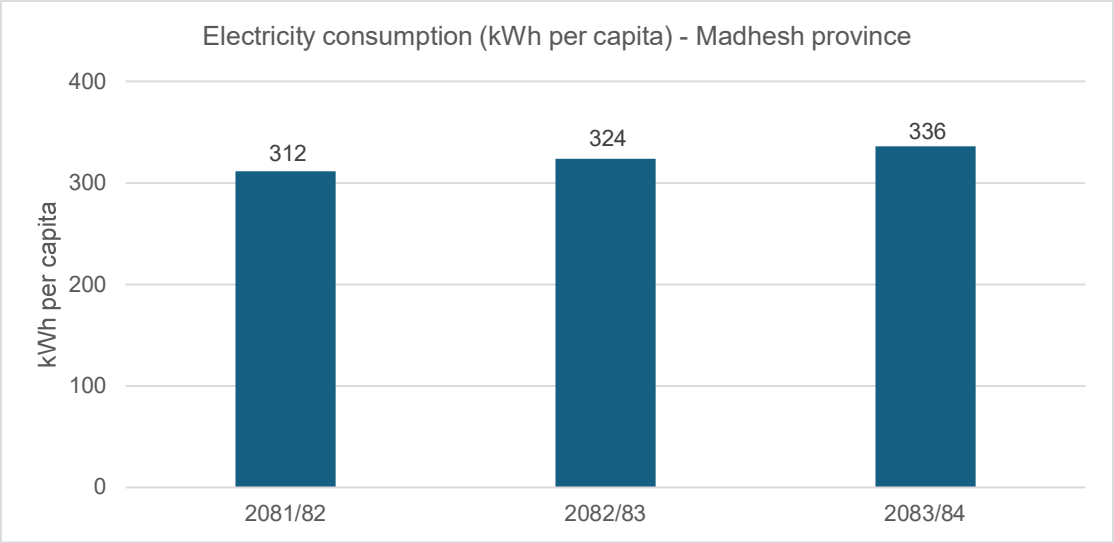


Figure 27: Electricity consumption (kWh per capita)

Similarly, Figure 28 shows the residential electricity consumption of Madhesh province from FY 2081/82 to 2083/84. The residential electricity consumption in 2081/82 is 690 kWh, which will gradually increase to 754 kWh by 2083/84.

For reference, the national average residential energy consumption was 672 kWh in 2079/80 (WECS, 2024).

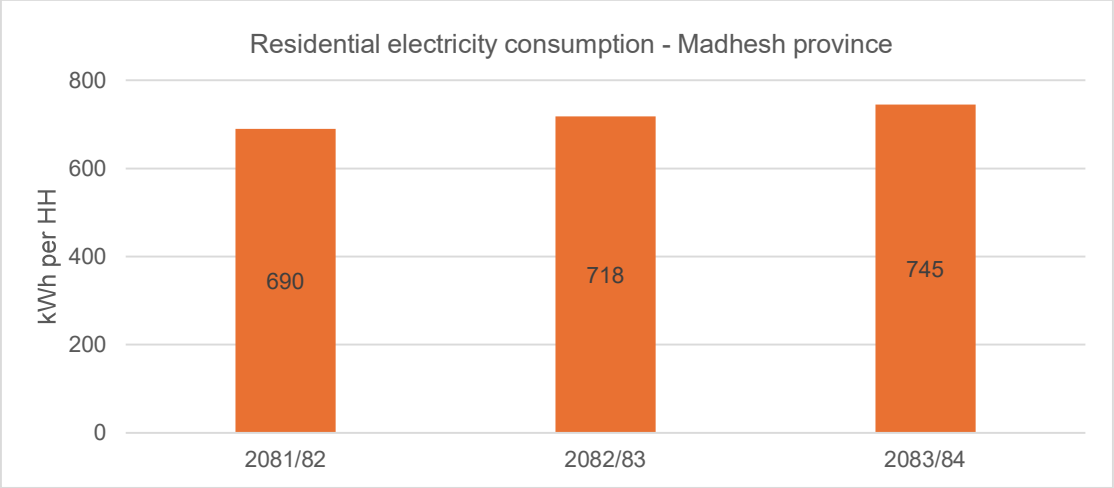


Figure 28: Residential electricity consumption

The energy shares of the different categories of energy are shown in Figure 29. The traditional biomass energy consists of fuelwood, agri-residue, and animal dung and accounts

for 78.7% of the total consumption in 2081/82. The total renewable energy comprises biogas, wind/solar (hybrid), micro-hydro, solar, and national grid electricity, and accounts for 2.23% of total consumption. Here, coal and petroleum products and imported electricity are accounted for as imported energy and account for 19.1% of the total consumption.

This shows that, in the coming years, biomass will continue to remain the highest share in the provincial energy mix.

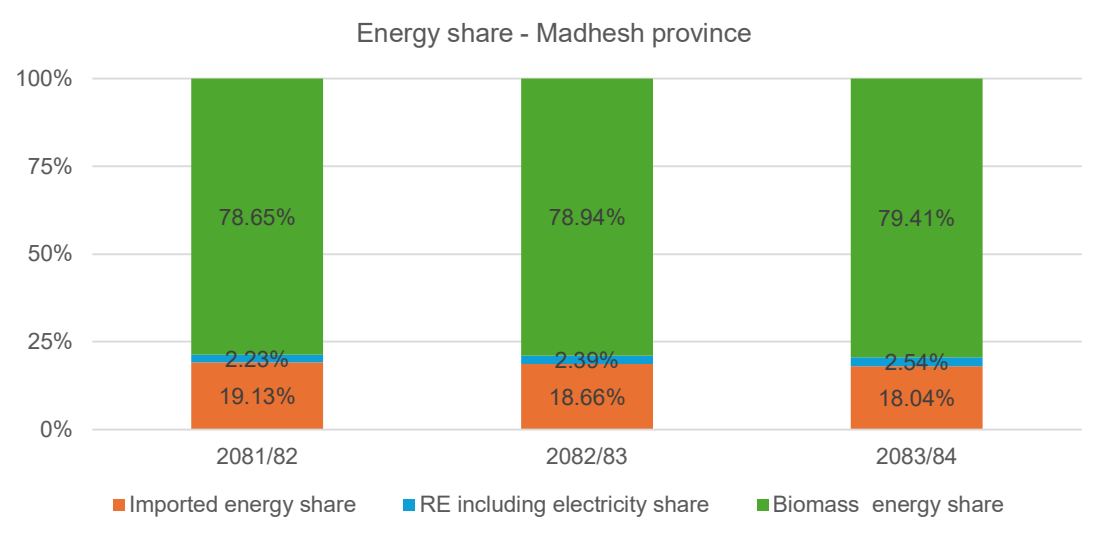


Figure 29: Energy share

8 Energy Pricing Trend

8.1 Trend in Pricing of Petroleum Products and Natural Gas

There are 371 fuel stations in Madhesh province. Figure 30 shows the petroleum fuel pricing over 2081 BS. All fuel types (petrol, diesel, kerosene, LPG, ATF DP and ATF DF) show a relatively stable trend over the year. LPG prices are the most stable, with no price changes. The overall cost of petroleum products has decreased over the year. The percentage of change of each fuel between the beginning of 2081 BS and the beginning of 2082 BS is:

Petrol	-10% (decrease)
Diesel	-9% (decrease)
Kerosene	-9% (decrease)
LPG	0%
ATF (DP)	-8% (decrease)
ATF (DF)	-8% (decrease)

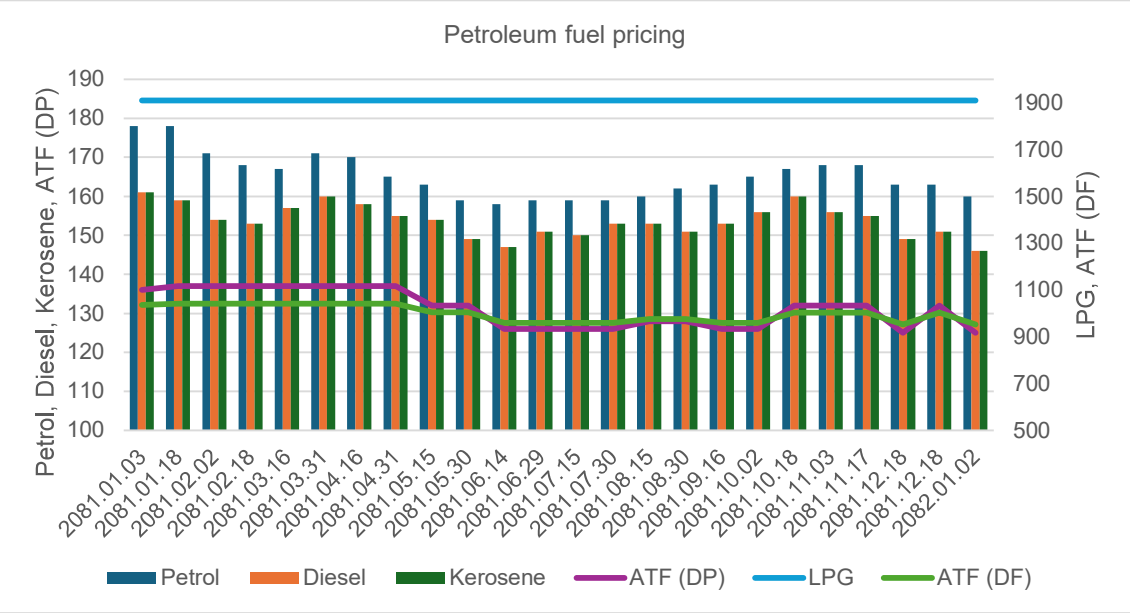


Figure 30: Petroleum fuel pricing trend (NOC, 2025)

8.2 Trend in Pricing of Electricity

The domestic tariff rates for single-phase low voltage (230 V), three-phase low voltage (400 V), and three-phase medium voltage (33/11 kV) are shown in Table 18, Table 19 and Table 20, respectively.

Table 18: Single-phase low voltage (230 voltage) (NEA, 2024)

kWh (monthly)	5 Ampere		15 Ampere		30 Ampere		60 Ampere	
	Minimum charge (NPR)	Energy charge (NPR/kWh)	Minimum charge (NPR)	Energy charge (NPR/kWh)	Minimum charge (NPR)	Energy charge (NPR/kWh)	Minimum charge (NPR)	Energy charge (NPR/kWh)
0-20	30	0	50	4	75	5	125	6
21-30	50	6.5	75	6.5	100	6.5	125	6.5
31-50	50	8	75	8	100	8	125	8
51-100	75	9.5	100	9.5	125	9.5	150	9.5
101-250	100	9.5	125	9.5	150	9.5	200	9.5
Above 251	150	11	175	11	200	11	250	11

Table 19: Three-phase low voltage (400 volt) (NEA, 2024)

kWh (monthly)	Up to 10 kVA			Up to 10 kVA		
	Minimum charge (NPR)	Month	Energy charge (NPR/kWh)	Minimum charge (NPR)	Month	Energy charge (NPR/kWh)
All consumers	1,100	Ashad - Kartik	10.5	1,800	Ashad - Kartik	10.5
		Marg - Jestha	11.5		Marg - Jestha	11.5

Table 20: Three-phase voltage (33/11 kV) (NEA, 2024)

kWh (monthly)	Minimum charge (NPR)	Month	Energy charge (NPR/kWh)
All consumers	10,000	Ashad - Kartik	10.5
		Marg - Jestha	11

9 Conclusion and Recommendations

Madhesh Province, home to 6.14 million people and contributing 13.1% to Nepal's GDP, stands at the forefront of Nepal's energy transition. Despite near-universal electrification, traditional biomass remains dominant, accounting for 78.7% of total consumption, driven by residential reliance on fuelwood and agricultural residue. Transportation and industrial sectors depend heavily on imported fossil fuels, exposing the province to energy insecurity and economic volatility. Madhesh's solar potential is unparalleled 149.7 GW, the highest in Nepal alongside 2,140 MW of utility-scale solar projects in development. Yet, modern renewable energy accounts for only 2.23%of total energy use.

Delving into the key findings, Madhesh Province emerges as a region of economic and demographic importance. In FY 2023/24, it accounted for 13.1% of Nepal's GDP, largely propelled by its agricultural sector and a population of 6.14 million. The energy balance for FY 2081/82 indicates a primary energy supply of 95,408 terajoules (TJ), with biomass leading at 34,249 TJ, predominantly fuelwood at 20,455 TJ, followed by imported petroleum products adding 47,117 TJ. On the demand side, the residential sector consumes the majority, making up 75% of the total 213,367 TJ, with biomass, especially 199,240 TJ from fuelwood, playing the dominant role. Meanwhile, the transportation sector depends almost entirely on petroleum products, utilising 11,349 TJ, while industrial, agricultural, and commercial sectors also lean heavily on fossil fuels and biomass. These statistics reveal a province where traditional energy sources remain deeply embedded, influencing both everyday life and economic activities.

The patterns of energy consumption in Madhesh underscore a significant reliance on traditional and imported resources. Biomass, constituting 73% of total consumption, drives most residential needs, particularly for cooking and heating. However, this extensive use brings about issues such as environmental degradation, deforestation, and health hazards from indoor air pollution, with a disproportionate impact on women and children. The transportation sector's near-total dependence on imported fossil fuels, totalling 47,117 TJ in FY 2081/82, leaves the province vulnerable to global price fluctuations and supply interruptions, placing additional strain on Nepal's foreign currency reserves. Although electricity is gaining traction, it contributes only 2.23% to the energy mix despite high grid penetration, suggesting that cleaner energy alternatives are not yet fully leveraged, hinting at considerable untapped potential.

Renewable energy opportunities

Amid these challenges, Madhesh Province stands out for its renewable energy prospects, especially in solar power. The province is endowed with an estimated solar capacity of 149.7 gigawatts (GW), the highest among Nepal's provinces, presenting a prime opportunity to diversify its energy sources. Presently, 2,140 megawatts (MW) of utility-scale solar projects are under development, signalling a hopeful shift toward sustainability. However, the province's wind energy potential is limited to 1.9 MW, and with no hydropower or geothermal projects in sight, other renewable options remain constrained. This solar advantage could prove transformative if supported by the right investments and policies to unlock its full potential.

Tackling energy efficiency and infrastructure hurdles

Energy efficiency and infrastructure present additional complexities for Madhesh. The report highlights substantial distribution losses, particularly with diesel, which reached 12,569 TJ in FY 2081/82, pointing to inefficiencies in the supply chain that require immediate attention. Per capita electricity consumption is recorded at 312 kilowatt-hours (kWh) in FY 2081/82, below the national average of 370 kWh, indicating limited access to modern energy services despite widespread electrification. Pricing trends show relative stability for petroleum products, and electricity tariffs are structured to accommodate various consumer categories, yet concerns about affordability and reliability persist, suggesting that enhancing infrastructure and access could significantly boost energy utilisation across the province.

Navigating the challenges ahead

The report identifies several hurdles that impede Madhesh Province's transition to a sustainable energy system. The over-reliance on biomass is a major concern, dominating the energy mix at 78.7% with 208,141 TJ used in FY 2081/82. This heavy dependence, especially for residential purposes, drives environmental damage, including a 1.4% deforestation rate from 2001 to 2023, and contributes to health issues from indoor air pollution, disproportionately affecting women and children. Switching to cleaner alternatives like electric or biogas cookstoves faces obstacles due to cultural preferences, high upfront costs, and limited awareness of these options. Additionally, the transportation and industrial sectors' dependence on imported petroleum products, totalling 47,117 TJ in FY 2081/82, poses energy security risks. With no domestic fossil fuel reserves, the province is exposed to global market volatility and geopolitical uncertainties, adding pressure to Nepal's economy.

Infrastructure limitations further complicate the picture. Even with high electrification rates, the quality of electricity supply varies, with rural areas experiencing outages and voltage fluctuations. The significant distribution losses, especially for diesel, highlight inefficiencies that demand substantial investment in grid modernisation and supply chain optimisation. The underutilised renewable potential, despite the province's solar strength, is another barrier, held back by financial constraints, a lack of technical expertise, and insufficient policy incentives. Finally, financial barriers pose a challenge, as developing renewable energy infrastructure and transitioning to clean cooking solutions requires significant investment, which is difficult given Nepal's financial constraints.

Opportunities

Despite these obstacles, Madhesh Province is brimming with opportunities, particularly by capitalising on its solar potential and aligning with Nepal's ambitious energy and climate goals, such as the Energy Development Roadmap 2081 BS and the Nationally Determined Contribution (NDC) 3.0. To transform these challenges into progress, several actionable recommendations can be pursued. Promoting electric cooking and grid strengthening is a critical step, given that biomass, including fuelwood, agricultural residue, and animal dung, accounts for 73% of Madhesh's energy demand at 208,141 TJ in FY 2081/82. This reliance leads to indoor air pollution, deforestation, low efficiency, and health issues, particularly for women and children, while fuel collection consumes valuable time. To counter this, Madhesh should advocate for electric and clean cookstoves, expand electricity access, encourage biogas and solar cookers, and raise awareness. This effort must be paired with a reliable power distribution network, necessitating close collaboration with the Nepal Electricity Authority (NEA) to enhance infrastructure and ensure a steady supply.

Scaling decentralised solar solutions offers another promising avenue. With a solar potential of 149.7 GW—the highest in Nepal—Madhesh is well-positioned to lead in renewable energy.

The provincial government should champion solar rooftop systems and Battery Energy Storage Systems (BESS) for commercial and industrial use, advance utility-scale solar photovoltaics to enhance the national energy mix, and promote hybrid (solar + grid) water pumping solutions for irrigation and drinking water. Public-private partnerships, a key focus of the 16th Five-Year Plan, can attract the investment needed to bring these projects to fruition. Enhancing energy efficiency is equally important, and adopting the National Energy Efficiency Strategy 2075 BS at the provincial level can reduce energy intensity and demand. Conducting energy audits, managing demand-side usage, and promoting energy-efficient appliances in homes and industries are essential steps, with awareness campaigns playing a key role in encouraging behavioural changes toward more sustainable energy practices.

Diversifying the energy mix with bioenergy presents further potential. The province's agricultural residue (7,186 TJ) and animal dung (6,608 TJ) provide a solid base for bioenergy development. Promoting biogas plants, supported by the Alternative Energy Promotion Centre (AEPC), can replace fuelwood for cooking and mitigate environmental harm. Exploring waste-to-energy systems, as outlined in the NDC, could further expand the energy mix and support rural growth. Strengthening policy and institutional coordination is vital for success, requiring robust collaboration between provincial and national bodies, including the Ministry of Energy, Irrigation and Water Supply, NEA, and AEPC. Simplifying regulatory frameworks and building technical capacity, as proposed in the White Paper 2075 BS, will streamline project execution, while involving local governments in decentralised energy planning, in line with the Rural Energy Policy 2006, can ensure community-tailored solutions.

Mobilising climate finance is another critical strategy. Nepal's Long-Term Strategy (LTS) for Net-Zero Emissions estimates a need for USD 33.04 billion by 2030 to meet NDC goals. Madhesh Province should tap into international climate finance to fund renewable energy projects and climate-resilient infrastructure. Domestic efforts, such as issuing green bonds and attracting private sector investment, can help bridge funding gaps and accelerate progress. Finally, aligning with national and global goals strengthens Madhesh's energy strategy. The Energy Development Roadmap 2081 BS targets 28,500 MW of installed capacity by 2035, prioritising renewables and electrification. The focus on clean cooking and efficiency supports Sustainable Development Goal 7 (Affordable and Clean Energy) and Goal 13 (Climate Action), while gender-focused efforts align with Goal 5 (Gender Equality), addressing the needs of vulnerable groups like women and children.

Future Scope

Madhesh Province stands at a defining moment in its energy journey. With its high population density, agricultural strength, and abundant solar potential, it has the foundation to become a leader in Nepal's sustainable development narrative. However, breaking away from biomass and fossil fuel dependence calls for a collective effort in policy implementation, infrastructure development, and community engagement. Prioritising electric cooking, expanding solar energy, and enhancing energy efficiency can reduce environmental and health impacts while driving economic growth. Robust institutional coordination and strategic use of climate finance will serve as the backbone of these initiatives, ensuring they take hold and flourish.

In conclusion, Madhesh Province stands at a transformative crossroads in its energy journey. With the highest solar potential in Nepal and widespread electrification, the province is well-positioned to lead the national transition toward clean and sustainable energy. Yet, entrenched reliance on traditional biomass and imported fossil fuels presents persistent challenges that undermine environmental resilience, public health, and energy security.

This Energy Sector Synopsis underscores the urgency for multidimensional reform. A robust shift toward electric cooking, decentralized solar, and bioenergy—coupled with investments in grid modernization and institutional coordination—is not only feasible but imperative. Mobilizing domestic and international climate finance, fostering public-private partnerships, and aligning with national strategies such as the Energy Development Roadmap 2081 BS and NDC 3.0 will be pivotal.

“With targeted investment and policy alignment, Madhesh Province can unlock its solar leadership to spearhead Nepal’s clean energy transition. This will require coordinated efforts across infrastructure, awareness campaigns, and climate finance mobilisation.”

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