

Review Article

Review of Energy Policies and Strategies in Nepal: Challenges and Opportunities

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Abstract

Nepal's energy sector is at a critical juncture, driven by the need for sustainability, energy security, and economic growth. This research examines Nepal's energy policies and strategies through PESTLE analysis, SWOT analysis, and a global comparative framework to assess key enablers, barriers, and future directions. The study explores government initiatives in hydropower expansion, renewable energy promotion, and carbon neutrality commitments, assessing their alignment with international energy transition trends. The PESTLE analysis evaluates political stability, economic viability, social implications, technological advancements, legal frameworks, and environmental sustainability in shaping Nepal's energy landscape. The SWOT analysis identifies strengths such as abundant hydropower resources, weaknesses including seasonal energy variability, opportunities in regional energy trade, and threats posed by climate change and investment constraints. Additionally, a comparative analysis of global energy policies highlights Nepal's position in the transition toward a low-carbon economy. Findings indicate that while Nepal has made notable progress in renewable energy adoption and policy development, challenges such as regulatory inefficiencies, inadequate grid infrastructure, and financial limitations persist. To ensure long-term energy security and sustainability, Nepal must prioritize effective policy implementation, public-private partnerships, and investment in smart grid technologies. This research provides a comprehensive framework for policymakers, industry stakeholders, and researchers, offering insights into optimizing Nepal's energy strategies in alignment with global best practices and emerging trends in clean energy development.

Keywords

Energy Policy, Sustainable Development in Nepal, Renewable Energy, Energy Security Framework

1. Introduction

Nepal, a landlocked South Asian nation, spans 147,516 sq. km, located between 26° 22'N to 30° 27'N latitude and 80° 4'E to 88° 12'E longitude. It is bordered by China to the north and India on the other three sides. The country extends 885 km east to west and 193 km at its widest north-south point. Geographically, Nepal is divided into three physiographic regions—Terai (23%), Hilly (42%), and Himalayan

(35%)—with altitudes ranging from 60 m to 8,848 m (Mount Everest).

Nepal's climate varies with topography and altitude, ranging from tropical in the Terai to tundra in the Himalayas. Temperatures fluctuate from 5°C to 47°C in the Terai, 0°C to 28°C in the Hilly region, and -16°C to below 0°C in the Himalayas. The country experiences monsoonal precipitation,

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with 80% of annual rainfall occurring between June and September. Nepal is rich in biodiversity, ranking 49th globally, but faces challenges in commercial energy resource availability.

The country possesses three major river basins—Koshi, Narayani, and Karnali, which contribute to immense hydropower potential. However, only a fraction of its estimated 83,000 MW capacity has been developed. While methane gas reserves exist, significant petroleum reserves remain undiscovered. Metallic minerals like copper, gold, lead, and zinc are present, but only lead and zinc are commercially viable.

Nepal's energy policies focus on hydropower expansion, renewable energy promotion, and carbon neutrality, aiming to reduce fossil fuel dependency and enhance regional energy trade. However, infrastructure, regulatory inefficiencies, and financial constraints remain key challenges in achieving sustainable energy security [1-6].



Figure 1. Digital Nepal Framework 2019.

1.1. Evolution of Energy Policies in Nepal

Nepal's energy policies have evolved significantly over the decades, reflecting a strategic shift towards sustainable and diversified energy development. The National Energy Strategy of 2013 established a foundational framework for comprehensive energy planning, prioritizing the advancement of hydropower and the seamless integration of renewable energy sources. Building upon this vision, subsequent policy interventions, notably the 2018 White Paper issued by the Ministry of Energy, Water Resources, and Irrigation (MOEWRI), articulated ambitious objectives, including a substantial increase in per capita energy consumption and the diversification of the national energy portfolio, with a targeted 20% contribution from renewable sources by 2030 [7-9].

1.2. Energy and Related Policies

Nepal's energy policy prioritizes hydropower utilization to meet domestic demand while expanding renewable energy

services. Various subsidy mechanisms support energy access and efficiency, with the National Rural Energy Programme (NREP) facilitating local implementation. The country aims to diversify its energy mix, targeting a 20% renewable share and increased industrial and commercial consumption.

The 2018 White Paper by the Ministry of Energy, Water Resources, and Irrigation (MOEWRI) outlines ambitious goals, including raising per capita electricity consumption from 700 kWh to 1,500 kWh within a decade. It envisions full electrification across sectors and aims to generate 3,000 MW of hydropower by 2021, scaling up to 5,000 MW in five years and 15,000 MW in ten. Domestic demand is projected to reach 10,000 MW, with plans for 200 MW of solar power in Madhesh Province. The strategy emphasizes clean energy optimization and efficiency improvements.

The Low Carbon Economic Development Strategy (LCEDS) by the Ministry of Population and Environment (MOPE) envisions Nepal's transition to a green economy. It promotes renewable energy adoption across key sectors—energy, agriculture, industry, transportation, and commerce—while aligning with national goals for reduced greenhouse gas emissions and sustainable development [10-13].

1.3. Second Nationally Determined Contribution

In December 2020, the Government of Nepal submitted its enhanced Nationally Determined Contribution (NDC) under the Paris Agreement for the 2021-2030 period, adhering to Articles 4.2 and 4.11, Decision 1/CP.21 (paragraphs 23 and 24), and other relevant provisions. The NDC sets ambitious sectoral targets, including expanding energy generation from approximately 1,400 MW to 15,000 MW, with 5-10% sourced from mini and micro-hydropower, solar, wind, and bioenergy.

In the transportation sector, the plan aims for electric vehicles to constitute 90% of private passenger vehicle sales. The residential sector targets a 25% adoption rate of electric cook stoves by 2025, alongside the installation of improved cook stoves in rural areas and the promotion of household and institutional biogas plants. These commitments underscore Nepal's strategic transition toward a sustainable, low-carbon future [14, 15].

1.4. Nepal: Sustainable Development Goals Status and Roadmaps 2016-2030

The National Planning Commission has developed a comprehensive status report and roadmap to achieve the Sustainable Development Goals (SDGs) by 2030. A key vision is Nepal's graduation from the Least Developed Countries (LDC) category, necessitating sustained economic growth of at least 7% annually. The roadmap identifies critical challenges and underscores the pivotal role of clean energy, agriculture, and tourism in fostering sustainable national prosperity.

The SDG targets emphasize (i) universal access to affordable, reliable, and modern energy services, (ii) a substantial increase in the share of renewable energy in the global energy mix, and (iii) a twofold improvement in global energy efficiency by 2030. Specific national targets include electrification of 99% of households, reducing LPG usage to below 40% by promoting electric cooking, and raising per capita electricity consumption to 1,500 kWh, necessitating an installed capacity of 15,000 MW.

Achieving these goals requires strategic interventions, including (i) expanding power generation through large hydropower projects, micro-hydro, and both off-grid and grid-connected solar systems, (ii) strengthening transmission and distribution networks, (iii) enhancing energy efficiency, and (iv) ensuring robust operation and maintenance (O&M) frameworks for a stable and high-quality power supply [15-20].

1.5. Nepal Electricity Regulatory Commission Act 2074

The Nepal Electricity Regulatory Commission Bill, enacted in 2017, established an independent regulatory body to ensure transparency in electricity generation, transmission, distribution, trading, and management. Its primary objectives include balancing supply and demand, setting fair electricity tariffs, fostering competition in the electricity market, and safeguarding consumer rights. With the establishment of this regulatory authority, Nepal's electricity sector is poised to evolve within a competitive framework that upholds stakeholder interests while ensuring electricity remains accessible, affordable, and sustainable [21-24].

1.6. Nepal's Energy Sector Vision 2050 A.D

Formulated in 2013, *Energy Vision 2050* outlines a strategic roadmap for harnessing Nepal's indigenous energy resources to sustainably meet the nation's growing energy demand. A key objective is to reduce dependence on imported petroleum products by substituting them with domestically available hydropower and other renewable energy sources. The vision identifies hydropower as the primary energy resource to drive long-term national energy security across all sectors.

Projected electrification targets necessitate an installed power capacity of 4,100 MW by 2020, 11,500 MW by 2030, and 31,000 MW by 2050. Achieving these milestones requires sustained investments, with the energy sector contributing approximately 2.4% of GDP. This vision underscores the critical role of a resilient and self-sufficient energy infrastructure in driving Nepal's economic growth and sustainability.

1.7. Nepal's 20-Year Renewable Energy Perspective Plan 2000-2020

The Renewable Energy Perspective Plan was formulated to

accelerate the development of Nepal's renewable energy sector, addressing the nation's rising energy demands. It provides a quantitative framework for the contribution of renewable energy to overall national energy consumption. In 2015, Nepal's installed renewable energy capacity stood at 35 MW, with a strategic target of expanding this capacity to 894 MW by 2030. The share of renewables in total energy consumption was 2% in 2015, with an ambitious goal of increasing it to 15% by 2030.

In 2015, small and micro-hydropower contributed 1.7% to the energy mix, while wind, solar, and biomass each accounted for 0.1%. By 2030, the plan aims to elevate the share of small/micro-hydropower to 9% and wind, solar, and biomass to 2%. Additionally, the number of domestic biogas plants is targeted to rise from 0.3 million in 2015 to 1.5 million, while the adoption of improved cookstoves is set to increase from 0.6 million to 2 million by 2030. To achieve these objectives, the plan outlines a robust institutional framework encompassing policy and regulatory reforms, capacity building, research and development, efficient implementation mechanisms, and strategic task prioritization. It serves as a comprehensive blueprint for fostering a sustainable and resilient renewable energy sector in Nepal [25-28].

1.8. National Energy Strategy of Nepal, 2013

The *Nepal Energy Strategy*, developed by the Water and Energy Commission Secretariat (WECS) with input from key stakeholders, provides a clear and comprehensive policy framework for the country's energy sector. It establishes a set of strategic objectives and policy principles that guide energy planning and development. The strategy also addresses critical sectoral challenges, including poverty alleviation, electricity access, clean and modern energy adoption, hydropower generation, environmental conservation, and mitigating health impacts caused by indoor air pollution.

A key priority of the strategy is the integration of energy planning within the existing sub-sectoral framework, ensuring alignment with socio-economic development and environmental sustainability. By 2030, the strategy aims to replace 30% of diesel and petrol vehicle demand with an equal share of electric and hybrid vehicles. Additionally, it emphasizes improving energy efficiency and transitioning from traditional fuels to cleaner alternatives, fostering a sustainable and resilient energy future for Nepal [29-34].

1.9. Nepal's Long-term Strategy (LTS) for Net-zero Emissions, 2021

The *Long-Term Strategy for Net-Zero Emissions*, formulated in 2021 by the Ministry of Forests and Environment, was officially submitted by the Government of Nepal at COP26. This strategy sets an ambitious target of achieving net-zero carbon emissions across both energy and non-energy sectors by 2045. To advance towards carbon neutrality, it outlines

stringent mitigation measures that demand bold policymaking, social transformation, and technological innovation.

Realizing this vision requires substantial financial resources, necessitating significant investments from both domestic and international funding institutions. The strategy's sectoral goals prioritize comprehensive electrification across all potential end-use services, reinforcing Nepal's commitment to a sustainable and low-carbon future [35-40].

1.10. Hydropower Development: A Cornerstone

Hydropower is the cornerstone of Nepal's energy strategy, playing a pivotal role in shaping the country's energy landscape and its economic growth. Given Nepal's geographical characteristics, with its vast mountainous terrain and abundant rivers, hydropower offers a substantial resource for power generation. The country is endowed with an estimated hydropower potential of around 83,000 megawatts (MW), which positions it as one of the most hydropower-rich nations in the world. However, the challenge remains in harnessing this vast potential and translating it into both domestic power supply and export opportunities [40-45].

1.10.1. Significance of Hydropower in Nepal's Energy Landscape

Hydropower not only serves as a crucial element of Nepal's energy security but also drives its socio-economic development. Approximately 90% of Nepal's total electricity generation comes from hydropower, highlighting the country's dependence on this renewable source of energy. The availability of clean, renewable energy aligns with global sustainability goals, and Nepal has made significant strides in promoting hydropower as an environmentally friendly source of energy.

1.10.2. Government Policies and Strategic Priorities

The government of Nepal has prioritized the development of hydropower projects in its long-term energy plans. The primary focus of these policies is to accelerate the growth of large-scale hydropower projects, which are seen as critical for

meeting both the domestic energy demands and for positioning Nepal as an energy exporter in the region. Alongside large-scale projects, there has been an increasing emphasis on micro-hydropower projects to provide energy solutions to rural and remote areas. These micro-hydropower plants are a key part of the government's efforts to improve rural electrification, providing electricity to underserved communities, boosting local economies, and enhancing living standards.

The government's commitment to hydropower development is outlined in several strategic documents, with the most notable being the *White Paper 2018*. This document articulates the vision for Nepal's energy future and sets ambitious targets. One of the key objectives outlined in the White Paper is the generation of *15,000 MW of electricity by 2030*. This target is part of Nepal's broader goal to achieve energy self-sufficiency, reduce dependency on imported fossil fuels, and promote clean energy solutions. By reaching this target, Nepal aims to meet its domestic energy needs and create a surplus that could be exported to neighboring countries such as India Bangladesh and China [46-50].

1.10.3. Renewable Energy Policies and Frameworks

Nepal's commitment to renewable energy is evident in initiatives like the National Rural Energy Programme (NREP) and the Alternative Energy Promotion Centre (AEP). Solar, wind, and biogas technologies are promoted through subsidies and grants. The government envisions decentralized renewable energy systems for rural areas, contributing to the SDG-7 target of universal energy access by 2030 [51-60].

1.10.4. International Commitments and Climate Goals

Under the Paris Agreement, Nepal has submitted its Nationally Determined Contribution (NDC) with targets to achieve 90% electric vehicle penetration in the transport sector and increase electric cooking to 25% of households by 2025. The Long-term Strategy (LTS) for Net-zero Emissions, submitted at COP26, underscores Nepal's commitment to achieving carbon neutrality by 2045 [60-66].

2. Literature Review

Table 1. Key Findings of Literature Review.

Section	Key Findings	Relevant Studies
Introduction	Energy policies in Nepal play a crucial role in sustainable development, economic growth, and environmental preservation. Various studies explore Nepal's renewable energy potential, policy interventions, smart grid applications, and energy efficiency measures.	[1-3, 7]
Renewable Energy Technologies and Sustainability	Identifies key challenges and opportunities in Nepal's renewable energy sector, focusing on policy gaps, financial constraints, and infrastructure development. Nepal's hydropower potential is significant but hindered by bureaucratic hurdles.	[1, 4, 9, 13, 15]
Policy and Govern-	Discusses policy inconsistencies, institutional barriers, and the need for long-term strategic	[7, 12, 21, 22, 60,

Section	Key Findings	Relevant Studies
Policy Framework	Planning to ensure energy security. Policy interventions can reduce energy consumption and mitigate environmental emissions in Nepal's industrial sector.	[61]
Smart Grids and Energy Transition	Explores the role of smart grid technology in Nepal, highlighting challenges and opportunities in modernizing the power system. Smart grids can enhance energy reliability and efficiency through proper policy support.	[31, 32, 45, 53]
Energy Storage and Distributed Generation	Examines hybrid energy storage solutions, distributed generation, and their impact on energy security. Highlights the benefits of capacitors and distributed energy resources in minimizing power losses.	[50-52]
Environmental and Economic Impacts	Evaluates the environmental consequences of Nepal's energy policies, emphasizing sustainable transitions to reduce carbon footprints. Economic analyses recommend restructuring subsidies and promoting public-private partnerships.	[14, 56-58, 60]
Global Context and Best Practices	Compares Nepal's energy policies with international frameworks, highlighting best practices from countries with successful renewable energy transitions. Discusses case studies from Germany, Denmark, and China on policy-driven energy sector transformation.	[10, 32, 26]

3. Methodology

SWOT analysis

Table 2. SWOT analysis of Nepal Energy policy.

Factor	Strengths	Weaknesses	Opportunities	Threats
Policy Framework	Government initiatives promoting renewable energy ([1, 2])	Lack of long-term policy stability ([7, 10])	Potential for policy alignment with international best practices ([26, 32])	Political instability affecting policy continuity ([58])
Renewable Energy	High hydropower potential ([4, 12])	Underutilization of solar and wind resources ([14])	Growing interest from foreign investors ([60])	Climate change impacting water availability ([56])
Infrastructure	Existing hydropower infrastructure ([10])	Inadequate transmission and distribution networks ([26])	Smart grid implementation possibilities ([32])	Aging infrastructure leading to inefficiencies ([58])
Investment & Funding	Availability of international funding ([26, 32])	Limited domestic investment ([7])	Public-private partnerships for energy projects ([60])	Risk of financial mismanagement ([56])
Energy Security	Potential to become an energy exporter ([14])	Dependency on imports for fossil fuels ([12])	Expansion of alternative energy sources ([58])	Geopolitical risks affecting energy trade ([10])
Global Context	International recognition of Nepal's renewable energy potential ([1, 4])	Slow adoption of global best practices ([7])	Learning from countries with successful energy transitions ([26])	Competition from neighboring countries in energy export ([60])

PESTILE analysis

Table 3. PESTILE analysis of Energy policy.

Factor	Description
Political	Government incentives, policy instability, and geopolitical influences on energy trade ([7, 10, 58])
Economic	Investment in renewable energy, financial constraints, and funding opportunities ([26, 32, 60])

Factor	Description
Social	Public awareness, community participation, and employment opportunities in the energy sector ([4, 12, 56])
Technological	Advancements in smart grids, energy storage, and efficiency improvements ([10, 26, 32])
Legal	Energy regulations, environmental laws, and international agreements ([7, 26, 60])
Environmental	Climate change, deforestation, and sustainability concerns ([14, 56, 58])

1. Porter's Five Forces Analysis

This framework evaluates the competitive forces shaping Nepal's energy sector.

Table 4. Porter's Five Force Analysis.

Force	Description
Threat of New Entrants	High setup costs and regulatory barriers make entry challenging, but growing incentives for renewables lower barriers ([4, 12]).
Bargaining Power of Suppliers	Nepal heavily relies on hydropower; limited diversification means suppliers hold significant influence ([10, 26]).
Bargaining Power of Buyers	Domestic consumers have limited energy choices, but industrial buyers have more influence ([7, 32]).
Threat of Substitutes	Fossil fuels, imports, and off-grid solutions pose competition to the national grid ([14, 56]).
Industry Rivalry	Regional competition from India and China in energy production and trade ([60]).

2. Energy Resilience Matrix

This matrix categorizes Nepal's ability to respond to energy crises.

Table 5. Energy Resilience Matrix.

Dimension	Current Status	Required Improvements
Infrastructure Resilience	Aging transmission network ([26])	Upgrading grid systems with smart solutions ([32])
Policy Adaptability	Frequent policy shifts ([58])	Long-term, stable policies with cross-sector collaboration ([7])
Energy Mix Diversity	Hydropower-dominated ([10])	Increased integration of solar and wind power ([12])
Investment Stability	International funding available ([60])	Need for improved domestic financial incentives ([26])

3. Policy Gap Analysis

This framework identifies gaps between Nepal's energy policy objectives and actual implementation.

Table 6. Policy Gap Analysis.

Policy Objective	Current Progress	Gap Identified
100% electrification by 2030	Rural electrification improving but not universal ([14])	Off-grid solutions and microgrids need expansion ([56])
Increased renewable energy	Hydropower at 90% but solar and wind negligible	Diversification needed to mitigate climate risks

Policy Objective	Current Progress	Gap Identified
share	([10])	([12])
Regional energy trade expansion	Agreements with India and Bangladesh ([26])	Infrastructure and policy barriers delay execution ([60])

4. Circular Economy Approach for Energy Sustainability

This approach assesses how Nepal can improve energy sustainability through resource efficiency and waste reduction.

Table 7. Approach for Energy Sustainability.

Principle	Current Implementation	Scope for Improvement
Energy Efficiency	Hydropower plants have inefficiencies ([10])	Upgrading to modern turbines and grid management ([26])
Waste-to-Energy	Limited bioenergy projects ([12])	Investment in waste-to-energy plants for urban centers ([60])
Recycling and Reuse	Battery recycling minimal ([56])	Establish e-waste management policies ([32])

Comparison of Nepalese Energy Policy with Other Countries

Table 8. Energy Policy Comparison Table.

Country	Policy Strengths	Policy Weaknesses	Best Practices for Nepal
Nepal	Strong hydropower base, international funding opportunities	Policy instability, weak transmission infrastructure	Long-term stable policies, diversified renewable sources
Norway	98% renewable energy, strong government incentives	High reliance on hydropower	Diversify energy mix, invest in smart grids
Germany	Strong solar and wind integration, robust energy transition policies	High costs, grid stability issues	Grid modernization, energy storage solutions
India	Expanding solar and wind projects, regional energy trade	Coal dependency, transmission challenges	Promote public-private partnerships, enhance regional trade
China	Massive renewable investments, energy storage advancements	Environmental concerns, regulatory complexity	Strengthen R&D in renewable tech, policy consistency

4. Key Challenges in Policy Implementation in Nepal

While Nepal has made significant strides in formulating progressive policies across various sectors, the country continues to face substantial challenges in the effective implementation of these policies. The gap between policy formulation and execution remains a persistent issue, preventing many ambitious goals from being realized. The primary obstacles to policy implementation in Nepal stem from

1. financial constraints

2. inadequate infrastructure
3. dependency on imported technologies among others.

To Addressing these challenges requires a comprehensive approach, including

1. institutional capacity building
2. private sector engagement
3. international collaboration

(1) Financial Constraints

One of the most pressing challenges in Nepal is the lack of sufficient financial resources to support the implementation of policies, especially those requiring substantial investment in infrastructure, technology, and human capital. Many of Nepal's ambitious policies, such as those related to hydropower

development, rural electrification, and sustainable infrastructure projects, require large upfront capital investments.

Nepal's financial resources are limited, and the country often faces budgetary constraints, especially in the face of competing demands from various sectors like health, education, and security. Furthermore, the country is heavily reliant on foreign aid and loans to fund development projects, which can introduce risks related to debt sustainability and donor dependency.

The limited domestic revenue generation capacity also affects the government's ability to fund and prioritize long-term projects. For example, while the government has set ambitious goals like generating 15,000 MW of electricity by 2030, achieving this target would require significant investments in hydropower infrastructure, technology, and workforce development. Without adequate funding mechanisms, these policies may remain stagnant or fall short of their intended outcomes.

(2) Inadequate Infrastructure

Nepal's infrastructure, particularly in terms of roads, transportation, energy, and communication, remains underdeveloped, which poses significant barriers to the effective implementation of policies. While the country's hydropower potential is vast, the absence of modern infrastructure, such as robust power transmission lines and efficient road networks, prevents the effective harnessing and distribution of resources.

In rural and remote areas, the lack of roads and transport networks can make it extremely difficult to bring in the necessary equipment for large-scale projects or to maintain micro-hydropower plants, agricultural initiatives, or industrial development. For example, even though micro-hydropower projects could contribute significantly to rural electrification, poor road access often hinders the timely and efficient construction and maintenance of these systems.

Similarly, the transmission and distribution network for electricity is outdated and insufficient in many parts of the country. This hampers the goal of electrifying rural areas and exporting electricity to neighboring countries. Without modernizing these infrastructure systems, the implementation of energy policies such as the White Paper 2018's target of 15,000 MW by 2030 may be unrealistic.

(3) Dependency on Imported Technologies

Nepal's technological landscape is heavily reliant on imported technologies, which poses significant challenges to the country's ability to implement policies effectively. This dependency is particularly evident in sectors such as energy, manufacturing, and infrastructure development. For instance, hydropower projects often require advanced turbine technology, electrical equipment, and construction materials that are not manufactured domestically. This reliance on foreign imports increases project costs, creates delays in implementation, and reduces the overall sustainability of these initiatives.

Furthermore, the country lacks a strong research and development (R & D) ecosystem to foster domestic innovation

in technology. Without local expertise and indigenous technologies, Nepal faces challenges in becoming self-sufficient in key sectors. In energy, for instance, while Nepal has abundant water resources for hydropower, the absence of domestic manufacturing capabilities for power generation and transmission equipment means that the country remains dependent on foreign suppliers.

This dependency not only limits policy implementation but also restricts Nepal's ability to build technological expertise within its own workforce. Moreover, over-reliance on foreign technologies can result in higher operational costs, and delays in importing parts or technologies can significantly impact the implementation timelines of key projects.

(4) Institutional Capacity and Governance Issues

Another major challenge to policy implementation in Nepal is the institutional capacity of government agencies. While policies may be well-designed, the ability of the implementing agencies to carry them out effectively is often compromised by weak institutional structures, insufficient human resources, and inadequate technical expertise.

Nepal's public institutions frequently face challenges related to bureaucratic inefficiency, lack of coordination, and political interference. In many cases, the implementation of policies gets delayed or derailed due to overlapping responsibilities, unclear mandates, or frequent changes in leadership within key government institutions. Additionally, there is often a shortage of skilled professionals in the public sector to manage complex projects.

For example, in hydropower development, institutions like the Department of Electricity Development (DoED) and the Investment Board Nepal (IBN) face challenges related to project approvals, land acquisition, and environmental clearances, all of which require coordination among multiple government agencies. Delays in these processes hinder progress and create uncertainty for investors and project developers.

(5) Private Sector Engagement

The role of the private sector in policy implementation is crucial for accelerating development, particularly in areas like infrastructure and technology. However, in Nepal, the private sector has often been slow to engage due to regulatory hurdles, complex bureaucratic procedures, and limited access to financing.

The government has made efforts to encourage private sector participation in areas such as hydropower, manufacturing, and services, but the challenges of policy implementation are often exacerbated by the lack of investor confidence. Issues such as lack of clarity in policy, high risk, and inconsistent legal frameworks discourage private sector investment. In addition, the absence of a strong business environment—marked by issues like corruption, red tape, and political instability further dissuades private players from fully participating in the country's development initiatives. To overcome this, the government needs to create a more favorable investment climate by offering incentives, streamlining bureaucratic processes, and building trust with the private sector.

(6) International Collaboration

Given Nepal's financial and technological limitations, international collaboration plays a critical role in supporting policy implementation. Nepal has benefited from international assistance, expertise, and technology transfer in sectors like energy, education, and infrastructure. However, the potential of international partnerships has not always been fully realized due to lack of coordination and misalignment between donor priorities and national policies.

To strengthen policy implementation, Nepal must foster better relationships with international partners, ensuring that development aid is channeled effectively toward critical projects. This includes improving the management of foreign aid, ensuring that projects align with national priorities, and ensuring transparency and accountability in the utilization of funds. Moreover, international cooperation in areas like technology transfer, capacity building, and knowledge exchange can provide Nepal with the tools and expertise needed to overcome its dependency on foreign technologies and build a more self-sufficient economy.

5. Future Directions and Recommendations in Nepal's Energy Policy Landscape



Figure 2. Conceptual multifaceted approach.

Nepal's energy policy landscape is at a critical juncture, with the country striving to meet ambitious energy goals while navigating challenges related to infrastructure, financing, and technology. To achieve these objectives, Nepal must adopt a multifaceted approach that focuses on

Below are several key directions and recommendations to guide Nepal's energy policy toward sustainable development.

1. Integrated Energy Planning

A crucial element for Nepal's energy future is the development of integrated energy planning. This approach would ensure that energy policies, projects, and technologies are aligned with long-term development goals, considering economic, environmental, and social factors. Integrated planning would facilitate the optimization of energy resources, such as hydropower, solar and wind, while addressing supply and demand fluctuations.

Key aspects of integrated energy planning include:

Comprehensive Energy Mix:

Nepal must diversify its energy sources to reduce dependence on a single resource, such as hydropower. While hydropower remains the cornerstone, integrating renewable sources like solar and wind energy will enhance energy security and sustainability. The country's renewable energy potential is vast and untapped in many regions, particularly in rural areas where solar and biomass could play a significant role.

Demand-Side Management:

Understanding the patterns of energy demand and implementing efficient demand-side management (DSM) policies will optimize the use of available energy. By promoting energy efficiency, Nepal can reduce peak demand and avoid unnecessary load shedding, making energy use more sustainable.

Grid and Decentralized Energy Systems:

Integrated planning should also include the development of both a robust national grid and decentralized energy systems, such as micro-hydro and solar-based off-grid solutions for rural communities. This approach would ensure that even the most remote areas can access electricity, fostering equitable energy development.

2. Strengthening Public-Private Partnerships (PPPs)

To accelerate the development of Nepal's energy sector, the government must actively encourage and facilitate public-private partnerships (PPPs). The public sector often lacks the financial resources and technical capacity to carry out large infrastructure projects alone. Involving the private sector can bring in the required capital, expertise, and innovation to achieve policy goals.

Key recommendations for strengthening PPPs include:

Policy and Regulatory Support: The government needs to create an enabling environment for private sector participation by offering clear, stable policies, attractive incentives, and fair regulatory frameworks. Streamlining licensing processes, simplifying land acquisition, and offering tax benefits are crucial to attracting private investments in the energy sector.

Risk Mitigation:

Private sector investment often comes with significant risks, especially in developing economies like Nepal. The government can play a vital role in reducing these risks by offering guarantees, such as sovereign guarantees for large infrastructure projects and providing investment insurance through international bodies or development banks.

Sector-specific Investment Funds:

Establishing dedicated funds for energy development, including renewable energy projects, would help mitigate financial barriers and attract private investors. This could include creating financing mechanisms that reduce the capital burden on developers and provide affordable long-term financing for large-scale projects like hydropower and wind farms.

3. Leveraging International Financing Mechanisms

Nepal's energy sector requires substantial investment, and while the government has made strides in mobilizing domestic resources, it will need to leverage international financing mechanisms to meet its energy goals. Nepal's existing dependence on foreign aid can be enhanced by attracting multilateral financing, climate change adaptation funds, and foreign direct investment (FDI).

Key avenues for leveraging international financing include:

Climate Finance and Green Funds:

Nepal can tap into international climate funds such as the Green Climate Fund (GCF), the Global Environment Facility (GEF), and the Clean Development Mechanism (CDM) to finance renewable energy projects, especially those related to solar, wind, and hydropower development. These funds often provide low-interest loans or grants, which can significantly reduce the financial burden on Nepal's energy sector.

Bilateral and Multilateral Partnerships:

Strengthening partnerships with countries and international financial institutions such as the World Bank, Asian Development Bank (ADB), and Norwegian Agency for Development Cooperation (NORAD) will help Nepal secure funding for large-scale infrastructure projects. These partnerships can also support technical expertise, policy advisory services, and capacity-building initiatives.

Carbon Credits and Clean Energy Projects:

Nepal can also explore carbon trading mechanisms and monetization of carbon credits from clean energy projects. This approach would attract investors interested in supporting Nepal's efforts in mitigating climate change through renewable energy projects.

4. Enhancing Grid Infrastructure

Nepal's power grid infrastructure is currently inadequate to handle the growing demand for electricity, as well as the potential surplus from large-scale hydropower and renewable energy projects. Strengthening the national grid infrastructure is vital for ensuring that energy generated from remote hydropower plants or decentralized renewable energy sources can be efficiently transmitted to urban and rural areas.

Key recommendations for enhancing grid infrastructure include:

Upgrading Transmission Lines:

Nepal needs to invest in modernizing and expanding its transmission and distribution lines to handle higher loads and reduce power losses. The grid should be upgraded to incorporate modern smart-grid technologies that can improve effi-

ciency, detect faults, and optimize electricity distribution.

Regional Grid Connectivity:

Nepal should work towards greater integration with neighboring countries, particularly India and China, to facilitate regional power trade. A robust cross-border grid infrastructure will enable Nepal to export surplus electricity to these countries and improve its energy security by importing power when necessary.

Grid Modernization with Smart Technology:

The integration of smart grids and advanced metering infrastructure (AMI) can optimize grid operations, enhance energy efficiency, and improve the overall reliability of the electricity supply. Smart grids also allow for the integration of renewable energy sources, as they can handle fluctuating energy production levels from solar and wind.

5. Adopting Advanced Energy Storage Solutions

One of the major challenges associated with renewable energy, particularly solar and wind, is the variability in energy production. To address this, Nepal must invest in advanced energy storage solutions that can store excess electricity generated during periods of low demand and release it during peak demand times.

*Key recommendations for energy storage include:**Battery Storage Systems:*

Investment in battery storage technologies, such as lithium-ion batteries, could provide a viable solution to storing electricity from intermittent renewable sources. These systems would allow the energy produced by solar and wind farms to be stored and distributed when required, ensuring a consistent energy supply.

Pumped Hydro Storage:

Nepal's mountainous terrain makes it ideal for pumped hydro storage projects, which can store excess electricity generated during off-peak hours and release it during high-demand periods. This is a proven technology used globally to balance intermittent renewable energy sources and improve grid stability.

Grid-Scale Storage:

Large-scale energy storage solutions could be integrated into the national grid to help stabilize fluctuations in renewable energy production, enhance grid reliability, and reduce reliance on fossil fuels.

6. Promoting Energy Efficiency

Enhancing energy efficiency is a fundamental aspect of ensuring that Nepal's energy sector develops sustainably. Efficient use of energy can help reduce energy consumption, lower costs, and decrease environmental impacts.

*Key strategies for promoting energy efficiency include:**Energy Efficiency Standards:*

Establishing energy efficiency standards for industries, buildings, and appliances is crucial. The government should implement energy performance labeling for appliances and incentivize the adoption of energy-efficient technologies in industrial processes.

Public Awareness Campaigns:

The government must launch awareness campaigns to educate the public on the importance of energy conservation. These campaigns could promote the use of energy-efficient lighting, insulation, and green building technologies.

Industrial Energy Efficiency:

Encouraging industries to adopt energy-efficient practices, such as the use of waste heat recovery systems and energy-efficient machinery, will reduce energy demand and costs, promoting a more sustainable industrial base.

Charting the Future of Nepal's Energy Policy

To achieve its ambitious energy goals, Nepal must adopt an integrated approach that combines strategic planning, innovative technologies, strong partnerships, and efficient use of resources. By focusing on energy diversification, private sector engagement, regional cooperation, and sustainable practices, Nepal can lay a solid foundation for a future of energy security, economic growth, and environmental sustainability. Moving forward, the government must prioritize energy infrastructure development, encourage international investments, and foster local technological advancements to ensure a resilient, clean, and sustainable energy system for the future.

6. Conclusion

Nepal's energy policies and strategies reflect a strong commitment to sustainable development and climate resilience. By addressing implementation challenges and leveraging its vast renewable resources, Nepal can achieve energy security, reduce its carbon footprint, and foster inclusive economic growth.

Abbreviations

AEPC	Alternative Energy Promotion Centre
AMI	Advanced Metering Infrastructure
ADB	Asian Development Bank
CDM	Clean Development Mechanism
COP26	26th Conference of the Parties to the UNFCCC
DSM	Demand-Side Management
DoED	Department of Electricity Development
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GCF	Green Climate Fund
GEF	Global Environment Facility
kWh	Kilowatt-hour
LCEDS	Low Carbon Economic Development Strategy
LDC	Least Developed Countries
LPG	Liquefied Petroleum Gas
LTS	Long-Term Strategy
MW	Megawatt
MOEWRI	Ministry of Energy, Water Resources, and Irrigation

MOPE	Ministry of Population and Environment
NDC	Nationally Determined Contribution
NEA	Nepal Electricity Authority
NERP	National Rural Energy Programme
NORAD	Norwegian Agency for Development Cooperation
O&M	Operation and Maintenance
PPP	Public-Private Partnership
PV	Photovoltaic
R&D	Research and Development
SDG	Sustainable Development Goals
UNFCCC	United Nations Framework Convention on Climate Change
WECS	Water and Energy Commission Secretariat

Conflicts of Interest

The authors declare no conflicts of interest.

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