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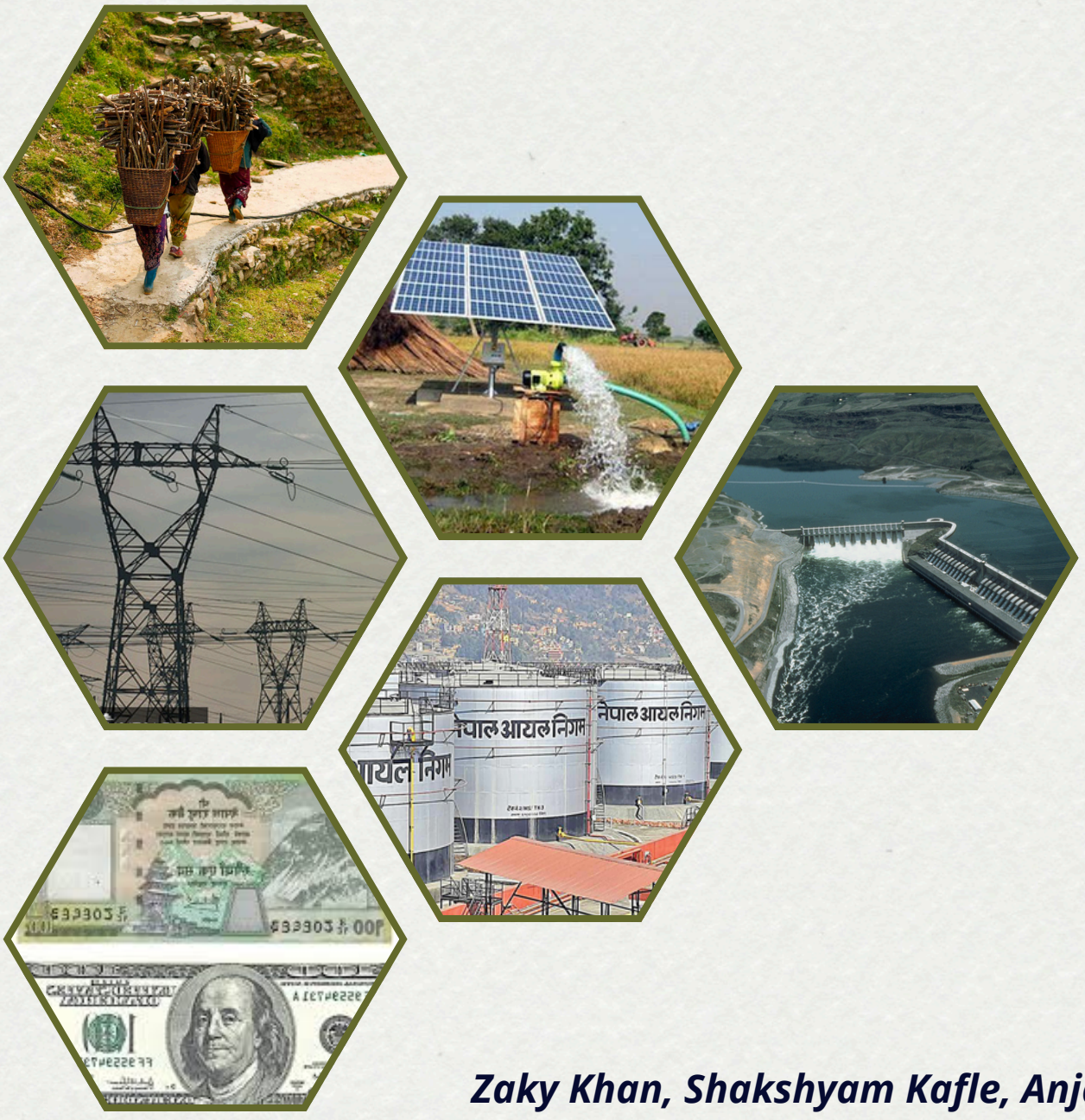
Policy Brief 2026

The Energy Sector in Nepal: Economic Potential and Financial Challenges of Renewable Energy Transition



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Abstract

Nepal's commitment to harness its vast renewable potential under the Third Nationally Determined Contribution (NDC 3.0) presents a transformative opportunity with economic and environmental benefits. It aims to capitalize on domestic hydropower and solar potential to ensure energy security, achieve higher economic growth, and reduce reliance on traditional biomass and petroleum imports. In this brief, we utilize IFPRI's dynamic Computable General Equilibrium (CGE) model calibrated to the 2022 Nepal's Social Accounting Matrix to measure the economic benefits of achieving the NDC 3.0 electricity capacity targets through a diversified renewable mix. Two scenarios were analyzed: a Business-as-Usual (BAU) scenario and an ambitious renewable expansion scenario aligned with NDC 3.0 goals but with accelerated emphasis on solar power, modeled at 15,000 MW from solar and other renewables, with the remainder from hydroelectricity. Integrating solar with hydropower emerges as a highly promising scenario for Nepal's energy landscape, leveraging the country's vast solar potential while building resilience against climate-related risks to hydroelectricity. This integrated approach represents a strategic and effective pathway toward achieving Net-zero. Model results indicate that such renewable transition generates substantial macroeconomic and welfare benefits. Achieving the NDC 3.0 aligned targets would expand the Nepal's economy by 2.2% by 2035 over the BAU scenario, generating over 82,000 new jobs, and lifting more than 36,000 people from poverty. Although renewable energy transition presents a huge economic opportunity, its benefits hinges on the country's ability to secure financing, implement policy reforms, and ensure equitable distribution. Without strategic financial planning and coordinated policy reforms, Nepal risks replacing existing energy dependencies with new vulnerabilities even as it pursues long-term sustainability.

Key Messages

- ✓ **Strong economic gains from renewable energy expansion:** Achieving the energy targets under the solar accelerated scenario expands Nepal's economy by 2.2% over the baseline by 2035, generating more than 82,000 jobs, and lifting over 36,000 people from poverty.
- ✓ **Uneven distribution of economic benefits:** Income gains under the NDC 3.0 aligned scenario disproportionately benefit higher-income households, highlighting the need for targeted policies to ensure a fair and inclusive transition.
- ✓ **Persistent dependence on traditional biomass despite vast renewable potential:** Nepal continues to rely heavily on traditional biomass even though it possesses significant hydropower and solar potential. However, achieving renewable expansion faces major barriers, including higher capital requirements of around 17.6 billion USD and land acquisition challenges.

1. Introduction

Nepal's energy sector faces a fundamental structural challenge. Despite an abundance of renewable resources, particularly hydropower and solar, the country remains heavily dependent on inefficient and imported energy sources. Traditional biomass accounts for approximately 64% of Nepal's primary energy consumption, amounting to around 532.42 PJ in 2023, while petroleum imports constitute nearly 15% of the total import bill (WECS, 2024).

This dependence on traditional sources has direct consequences. It contributes to low per capita electricity consumption, which at 177 kWh per annum in 2018 was one-twentieth of the global average. This is despite the country's immense renewable endowment, including one of the world's richest hydropower potentials, estimated at approximately 83 gigawatts (GW) technically feasible and 42 GW economically viable (Gunatilake et al., 2020).

Although electricity generation is expanding, its utilization remains hampered. The system is dominated by hydropower (about 95% of installed capacity), more than half of which comes from run-of-the-river (ROR) projects. These ROR projects cannot meet demand during the dry season, forcing costly electricity imports, while surplus power in the wet season is exported at lower rates. This pattern underscores systemic inefficiency and critical vulnerability in the power sector. (AEPC,2024).

The global climate commitments, particularly the Paris Agreement, underscore the imperative for nations to achieve economic growth while simultaneously reducing greenhouse gas emissions. In Nepal, over-reliance on traditional biomass and imported fossil fuels directly results in significant GHG emissions, exacerbating environmental degradation and creating a critical development bottleneck.

Transitioning to renewable energy is therefore not merely a climate obligation but a core strategy for achieving Nepal's sustainable development objectives. It offers a pathway to enhanced energy security, improved public health, and reduced import burdens. Within renewable resources, hydropower and solar power are crucial due to their vast potential and scalability.

Hydropower is a cornerstone for Nepal's economic development. The sector's contribution to GDP has more than doubled from 1.10% in 2011/12 to 2.64% in 2023/24 (Nepal Rastra Bank, 2024). With 42 GW of economically viable capacity, only around 5% of the potential has been utilized (Gunatilake et al., 2020).

To address the seasonal imbalance and diversify the energy mix, solar power presents a strategic solution. Nepal is endowed with significant solar resources, receiving 4.5–5.5 kWh/m²/day of solar radiation, with a technical potential exceeding 50 GW (Shrestha & Bajracharya, 2021). Its versatility is demonstrated through multiple pathways, from grid-scale and rooftop systems to off-grid solutions and agricultural applications like irrigation pumps. Critically, solar generation peaks during the dry season, which can complement hydropower, optimize water use in reservoirs, and directly address the seasonal supply imbalance.

Recognizing these challenges and opportunities, Nepal's Nationally Determined Contributions

(NDCs) 3.0 document outlines a strategy to expand electricity generation capacity from renewable resources to 28,500 MW by 2035 (MoFE, 2025). By leveraging Nepal's abundant renewable resources, the strategy aims to reduce reliance on traditional biomass and petroleum imports, enhance energy security, and lower emissions. The ambitious targets set forth in NDC 3.0 are also intrinsically linked to the goals of poverty reduction, employment generation, and sustainable economic growth. Accordingly, this policy brief aims to assess the potential economic impacts of this electricity capacity expansion by using a Computable General Equilibrium (CGE) model to understand how this transition could influence Nepal's economy.

2. Policy Landscape of Energy Sector

Nepal's policy framework for expanding renewable energy is shaped by a series of national plans and climate commitments. This includes the 15th National Plan target of 5000 MW by the end of FY 2023/24 (Nepal Planning Commission, 2020), the second NDC unconditional target of 15,000 MW of clean electricity by 2025, and the current 16th Five-Year Plan aiming for 11,800 MW of generation capacity by 2028/29 (Nepal Planning Commission, 2024). Building on these earlier commitments, NDC 3.0 outlines the following key targets (MoFE, 2025):

Expansion of renewable and hydropower generation capacity

Expansion of hydropower generation to 14,031 MW by 2030 and 28,500 MW by 2035. This target includes 10% by 2030 and 15% by 2035 from mini- and micro-hydro power, solar, wind power, and bioenergy.

Transmission and distribution loss reduction: Decrease total system transmission and distribution losses to 11.5% and 10.5% by 2030 and 2035, while upgrading the transmission and distribution lines and substation capacity to ensure reliable and efficient supply of electricity.

Expanding clean and renewable cooking energy:

Expand electric cookstoves to 2.1 million households and 15,000 institutions by 2035. Additionally, NDC 3.0 aims to expand improved cookstoves to 1 million households, and metallic improved cookstoves to 100,000 households. Biogas adoption is also prioritized, with targets of 650,000 household biogas systems and 750 large-scale biogas plants, supporting a shift toward efficient, low-emission cooking technologies.

Despite the ambitious strategy of NDC 3.0, Nepal's long-term planning documents present a more conservative picture. The Energy Sector Vision 2050, published by the Ministry of Energy, Water Resources, and Irrigation (MoEWRI, 2013) projects hydropower capacity reaching only 15,841 MW by 2050, significantly below the commitments under NDC 3.0. This discrepancy illustrates a policy coherence challenge, as the targets from the Energy Sector Vision 2050 do not align with the NDC targets. This misalignment raises the question whether NDCs 3.0 near and medium-term targets are too ambitious within the limited time available, even with the availability of international climate finance and support.

Ensuring coherence across planning documents will be essential for guiding investment priorities and sustaining Nepal's renewable energy transition.

3. Nepal's Energy Sector's Future: Economy-wide Effects-Methodology and Results

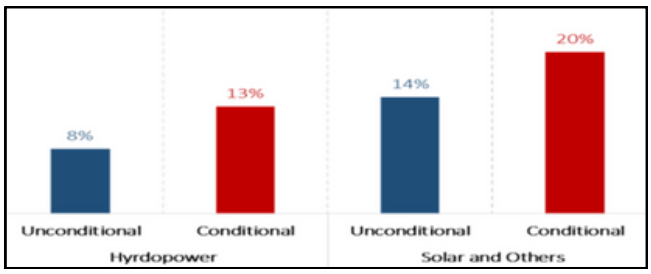
We employ an economywide model for Nepal to assess the impact of the successful completion of NDC 3.0 aligned energy targets. IFPRI's dynamic computable general equilibrium (CGE) model (Thurlow, (2008)), which is calibrated to a recent Social Accounting Matrix (SAM) of Nepal has been used to measure the impact on Nepal's economy (IFPRI, 2024). Using this model, we run two scenarios with the following description:

Business-as-Usual (BAU) Scenario:
This scenario assumes a continuation of the historical annual growth rate in electricity generation without any new major policy or NDC's interventions. It projects Nepal's economic trajectory to 2035 based on the historical trends in key drivers such as population growth, factor productivity, investment, and remittances.

NDC 3.0 Scenario (Conditional):
This scenario simulates the achievement of Nepal's NDC 3.0 aligned target of expanding total electricity generation capacity from 3,500 MW to 28,500 MW by 2035. Nepal's NDC 3.0 allocates approximately 15% of total electricity generation capacity to solar power and other renewable resources. Building on this allocation, this study further assumes a more strategic pathway, in which solar and other renewable technologies together contribute approximately 15,000 MW by 2035 (approximately 52% of capacity).

Further, this scenario is modeled under the availability of foreign financing, as significant investment is required to generate electricity. Figure 1 illustrates how international financing fuels electricity production, which in turn helps boost economic growth. Conversely, the lack of funding significantly slows electricity generation, impeding Nepal's development. This scenario also includes a major exogenous increase in the capital stock and productive capacity of the solar and hydropower sectors.

Figure 1: Projected Growth in Electricity Production (average annual growth to 2035)



Source: Authors' estimates

The simulation outcomes are reported in Figures 2-4. Figure 2 highlights the contrast between the two scenarios, showing that switching to solar power, and increasing hydropower and total electricity generation delivers a stronger economic performance. Under the NDC 3.0 aligned scenario, expanding electricity capacity accelerates sectoral growth by 6.2 percentage points per year, double the sectoral growth rate observed in the baseline scenario. Since electricity is a

fundamental input across all economic sectors, its expansion raises national GDP by 0.18 percentage points annually, resulting in an economy that is 2.2% larger by 2035 over the baseline scenario.

Figure 2: Percentage change in GDP from BAU scenario in 2035

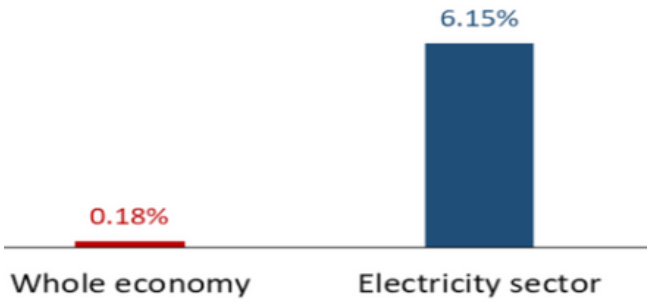
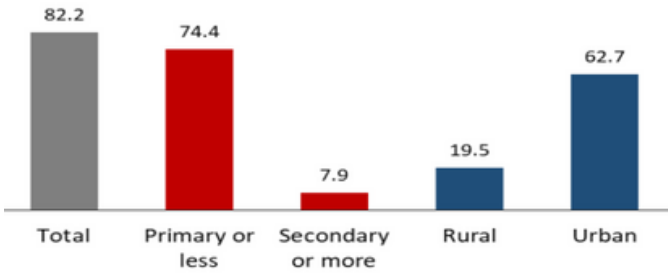


Figure 3 shows that the expansion of renewable energy under the NDC 3.0 aligned scenario creates approximately 82,000 new employment opportunities, mainly in urban areas (Figure 3). Most of these jobs, over 74,000, are for lower-educated workers. This expansion of energy also delivers significant gains in poverty reduction. Meeting the NDC 3.0 aligned targets raises the overall household incomes by 2.2% by 2035, driven by faster GDP growth and lower energy prices. However, these income gains are not equitably distributed; they disproportionately benefit higher-income households, whose incomes grow by 2.40%, as compared to 0.94% for poorer households. This variation in gains reflects the higher initial capital costs of energy technologies and varying consumption patterns. Despite the disparity, broad-based economic growth lifts a substantial number of people out of poverty, with around 36,000 fewer individuals living below the $2.15 per day poverty line by 2035 (Figure 4).

Figure 3: New jobs are created (1000 workers by 2035)



Source: Results based on model simulations

Figure 4: People lifted out of poverty (1000 people, $2.15 a day poverty line)

Source: Results based on model simulations

4. Caveat

This note is based on the ongoing collaborative research work, and the model assumptions are made based on the series of expert consultation meetings held in Kathmandu in February and May 2025. The analysis represents a first order assessment of the economy-wide impact of the expansion of the renewable energy in Nepal. As the research progresses, the analysis will include various policy trade-offs to accomplish NDC 3.0 target for energy sector.

5. Financial Considerations and Challenges

Achieving Nepal's NDC 3.0 aligned energy targets, which include developing 15,000 MW from solar and other renewables, presents significant financial and infrastructural hurdles. To meet these targets from a current baseline where solar contributes only about 3% of national generation (Thapa & Regmi, 2022), a massive scale-up is required. This analysis focuses on solar power as it is projected to form the dominant share of new capacity, due to its high scalability and shorter deployment timelines compared to other non-hydro renewables like biogas or mini-hydro, which face greater geographic and resource limitations for utility-scale expansion.

Consequently, the capital needed specifically for large-scale solar development is estimated at $17.6 billion USD, derived by applying the benchmark cost of NPR 165.2 million per MW (Basnet et al., 2023) to the projected solar capacity. Financing this scale of solar deployment remains a primary barrier, challenged by high upfront costs, a lack of concessional financing, and limited foreign investment.

The transition is further complicated by several key implementation challenges. Grid-scale solar requires approximately 1-1.25 hectares per MW, creating acute land acquisition constraints, particularly in the high-potential Terai Belt, where competition with agriculture and settlements is intense (Ghimire, 2025). Furthermore, solar's intermittency demands substantial investment in storage or complementary hydropower to stabilize a national grid that currently lacks the flexibility needed for large-scale renewable integration. Persistent policy and regulatory gaps such as licensing delays, limited feed-in tariffs, and weak net-metering incentives have dampened private-sector enthusiasm and investment.

A broader economic assessment underscores that, despite the long-term benefits of reducing fossil fuel imports, Nepal's clean energy transition will require massive, sustained capital investment not only in generation but also in transmission and grid infrastructure. This is a particular challenge in Nepal's mountainous terrain, where rugged geography inherently elevates construction and electrification costs.

6. Conclusion

The CGE model demonstrates that achieving the NDC 3.0 aligned energy targets is a strong economic strategy, with the potential to significantly expand the economy, generate employment, and reduce poverty. However, these gains are conditional on addressing the substantial financial and other key challenges, such as land consolidation, associated with scaling renewable energy. The transition requires high upfront investment, reliable foreign financing, and coordinated policy reforms. Without these, Nepal risks replacing its existing economic dependency, such as on imported fossil fuels, with a new dependency on external capital to finance costly infrastructure, undermining the long-term sustainability of the transition.

7. Policy Recommendations

The following integrated actions are recommended:

- ✓ **Secure Strategic Investment:**
  Develop innovative financing models and attract foreign direct investment targeted at renewable energy infrastructure, thus meeting high upfront capital requirements without straining public finances.
- ✓ **Ensure an Equitable Transition:**
  Design policies to ensure the benefits of lower energy costs and new jobs are distributed fairly, preventing the transition to disproportionately favor the high-income households. This could include targeted subsidies for electric cooking for low-income households.
- ✓ **Improve Policy Coherence:**
  Align all energy-related investments and policy reforms with NDC goals to avoid the risk of continued fossil fuel dependency and to ensure financial resources support towards a sustainable energy future.

8. Acknowledgement

The IIDS-IFPRI project focuses on integrating agrifood systems into climate and development policies ahead of COP30 in Brazil (2025). Furthermore, the study aims to provide model-based analysis to support Nepal's government in areas such as low-carbon agricultural technologies, sustainable energy transition, and transport sector mitigation strategies. It will also assess the macroeconomic impact of climate policies, financing options for low-carbon development, and socioeconomic risks of transition. Key activities include workshops with policymakers, sectorial diagnostics, economy-wide modeling, and a final report to be completed by March 2026. Finally, the study seeks to enhance Nepal's food security, resilience, and environmental sustainability.

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