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Integration Of Renewable Energy In Smart Infrastructure Development In Nepal: A Policy And Feasibility Review

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Abstract
Nepal's journey towards renewable energy and intelligent infrastructure is the need of the hour in order to achieve long-term energy security, environmental sustainability, and sustainable economic development. This study employs a framework of policy and feasibility review, incorporating national plan analysis, subsidy policy analysis, and institutional arrangement analysis under policy coherence, technical and financial viability, and stakeholder dynamics. Findings indicate high political will and large accomplishment in electrification, particularly rural electrification by hydropower and solar schemes, aimed at international goals such as SDG 7 (clean energy) and SDG 11 (sustainable cities). Nevertheless, application of renewable energy for smart urban infrastructure is retarded by aging power grids, lacking investment frameworks, and fragmented government. While Nepal has developed a robust policy framework, actual implementation would require combined efforts from government agencies, changing finance models, and the use of advanced technologies such as smart grids and storage. It recommends the formulation of public-private partnerships, the development of a harmonized renewable-smart city model, institutional capacity development, and the leverage of local innovation to upgrade renewable-smart infrastructure towards a low-carbon and resilient future.
Keywords: *Energy Policy, Renewable Energy, Smart Cities, Smart Infrastructure, Sustainable Development*

1. INTRODUCTION

Nepal's unique topography, characterized by mountainous terrains and numerous rivers, offers significant potential for renewable energy generation. The country's reliance on imported fossil fuels has prompted a shift towards harnessing indigenous renewable resources to achieve energy security, economic growth, and environmental sustainability. Integrating renewable energy into smart infrastructure is essential for modernizing Nepal's energy sector and meeting its development goals.

Nepal's transition to renewable energy (RE) and smart infrastructure is critical for achieving energy security, reducing carbon emissions, and fostering sustainable development. With abundant hydropower, solar, and wind resources, the country aims to transition to 100% RE by 2050 while modernizing its grid through smart technologies (Teske et al., 2023).

1.1. Current Energy Landscape

Nepal's energy mix is dominated by hydropower, complemented by solar, wind, and biomass. However, reliance on fossil fuels persists in transportation, industry, and residential sectors, contributing to energy insecurity and environmental degradation (T. N. Bhattarai et al., 2023).

Rapid urbanization in South Asia has brought significant challenges such as strained infrastructure, environmental degradation, and increasing energy demand. To address these issues, countries in the region are increasingly adopting smart city initiatives that leverage advanced technologies and sustainable energy solutions to improve urban living standards, resource efficiency, and resilience. Smart cities integrate digital infrastructure, renewable energy, and data-driven governance to create sustainable, inclusive, and economically vibrant urban environments. This regional trend aligns with global efforts to achieve the Sustainable Development Goals (SDGs), particularly SDG 7 (affordable and clean energy) and SDG 11 (sustainable cities and communities).

The table below presents the growth in installed renewable energy capacity (in megawatts) across South Asian countries from 2015 to 2024. The data illustrate significant progress in countries like India and Bangladesh, while Nepal and Bhutan also show steady increases, reflecting their commitment to expanding clean energy access as part of their smart infrastructure development. These trends underscore the growing importance of

renewable energy integration in urban and rural areas to support sustainable development and energy security in the region.

Table 1: Energy Landscape of SAARC Nations

Country	2015	2020	2021	2022	2023	2024
Afghanistan	303	401	418	522	522	522
Bangladesh	474	622	784	801	1,024	1,124
Bhutan	1,615	2,335	2,335	2,335	2,456	2,456
India	78,582	134,774	147,530	163,213	175,684	204,292
Maldives	6	21	42	54	57	70
Nepal	811	1,105	1,138	1,178	1,222	1,247
Pakistan	8,128	13,005	13,705	14,156	15,146	17,164
Sri Lanka	1,876	3,122	3,614	3,903	4,206	4,320

Source: IRENA, 2025.

1.2. Renewable Energy Landscape in Nepal

The renewable energy landscape in Nepal has shown steady growth and diversification over the past decade, driven primarily by hydropower but increasingly complemented by solar and bioenergy sources. According to the latest data from the Energy Sector Synopsis Report 2024 and other authoritative sources, Nepal's installed capacity of renewable energy has expanded from around 39 MW in 2015 to nearly 98 MW by 2024. Hydropower remains the dominant source, growing from 791 MW in 2015 to 3,293 MW in 2024. The table below demonstrates the diversity of renewable energy sources used in Nepal.

Table 2: Renewable Energy Landscape in Nepal

	2015	2020	2021	2022	2023	2024
Hydropower	791	1281	1971	2197	2675	3293
Solar Energy	13	64	90	111	117	175
Bioenergy	7	6	7	7	7	7
Wind energy	0	0	0	0	0	0
Geothermal energy	0	0	0	0	0	0
Off Grid Capacity						
Total renewable energy	39.314	86.713	89.397	93.101	93.101	98.285

Source: IRENA, 2025.

1.3. Hydropower Potential and Development

Nepal's hydropower potential is estimated at 83,000 MW, with approximately 45,000 MW considered technically and economically feasible (Baniya et al., 2023). As of 2024, the installed hydropower capacity reached 3,293 MW, marking significant progress from previous years (IRENA, 2025). The government aims to increase this capacity to 28,500 MW by 2035 to meet domestic demand and export surplus electricity to neighboring countries (ERC, 2024).

Table 3: Major Hydropower Projects in Nepal

Project Name	Capacity (MW)	Year Commissioned
Upper Tamakoshi	456.0	2021
Kaligandaki	144	2002
Rasuwagadi	111.0	2024
Solukhola Dudhkoshi	86.0	2023
Likhu-1	77.0	2024

Source: NEA, 2024.

1.4. Solar Energy Initiatives

Solar energy is gaining traction in Nepal, with several projects contributing to the national grid. Notable projects include the Nuwakot Solar Power Station (25 MW) and the Mithila 2 Solar PV Station of 10 MW (AEPC, 2024). These projects demonstrate the feasibility of solar energy integration into the national grid.

1.5. Wind and Biomass Energy

While wind and biomass energy have potential in Nepal, their development remains limited. The government has identified areas suitable for wind energy projects, and biomass energy is primarily used in rural areas for cooking and heating.

1.6. Smart City

Smart cities represent an innovative urban development paradigm that leverages digital technologies and data-driven solutions to enhance the quality of life, economic growth, and environmental sustainability. At their core, smart cities integrate information and communication technologies (ICT) with urban infrastructure to optimize resource management, improve public services, and foster citizen engagement. This approach aligns with the global shift towards sustainable urbanization, addressing challenges such as overpopulation, climate change, and resource depletion by promoting efficient energy use, sustainable mobility, and resilient infrastructure (Chen et al., 2024; Kozłowski & Suwar, 2021).

Renewable energy plays a pivotal role in powering smart cities, enabling them to meet sustainability goals while reducing greenhouse gas emissions and dependence on fossil fuels. By integrating solar, wind, hydropower, and other clean energy sources with smart grids and energy storage systems, smart cities can ensure reliable, affordable, and environmentally responsible energy supply (Almihat & Munda, 2025; Silva et al., 2025). This integration not only supports economic development and energy security but also enhances urban resilience and environmental stewardship, aligning with international frameworks such as the Sustainable Development Goals (SDG 7 and SDG 11) and the Paris Agreement (Dahmani, 2024; Hassan et al., 2024).

In the context of Nepal, the development of smart infrastructure incorporating renewable energy is essential for addressing the country's unique geographic and socio-economic challenges. Nepal's smart city initiatives focus on deploying digital technologies alongside renewable energy solutions to improve urban services, reduce energy losses, and promote sustainable growth. This integrated approach fosters inclusive, low-carbon urban environments that can adapt to future demands while preserving natural resources and enhancing citizens' well-being, thus contributing to Nepal's national and global sustainability commitments (Benjamen, 2025; Khatiwada & Aryal, 2024).

2. RESEARCH METHODS

This study adopts research design employing a policy and feasibility review framework. The research focuses on systematically analyzing existing national policies, programs, and institutional arrangements that govern renewable energy and smart infrastructure development in Nepal. It also assesses the feasibility of integrating renewable energy into smart infrastructure projects through secondary sources of data and expert perspectives.

2.1. Research Design

The research is descriptive and analytical in nature. It is primarily based on secondary data obtained from policy documents, government reports, international energy databases, scholarly journals, and case studies. The design allows for a comprehensive understanding of Nepal's current renewable energy policy environment and its intersection with smart infrastructure initiatives.

2.2. Data Collection Methods

Document Review

The study conducted an extensive review of:

- National energy and infrastructure policies (e.g., Renewable Energy Subsidy Policy 2016, National Energy Strategy, Smart City Guidelines, etc.)
- Legislative frameworks and master plans (e.g., NEA Development Plan, NDCs under the Paris Agreement)
- Reports from relevant government agencies such as:
    - Ministry of Energy, Water Resources and Irrigation (MoEWRI)
    - Alternative Energy Promotion Centre (AEPC)
    - Nepal Electricity Authority (NEA)

Academic Literature

Peer-reviewed journals, conference proceedings, and published research papers were reviewed to understand:

- Global trends in renewable energy and smart infrastructure integration

- Policy evaluation frameworks
- Renewable energy feasibility models relevant to developing countries

International Guidelines and Databases

The study incorporated insights from:

- IEA (International Energy Agency)
- IRENA (International Renewable Energy Agency)
- World Bank, ADB, and UN-Habitat smart city frameworks
- Sustainable Development Goal (SDG) documents, particularly SDG 7 and SDG 11

2.3. Analytical Framework

A thematic content analysis approach was employed, guided by the following thematic lenses:

- **Policy Coherence**: Alignment between renewable energy policies and urban infrastructure strategies.
- **Implementation Feasibility**: Technical, financial, and institutional feasibility of renewable integration.
- **Stakeholder Analysis**: Identification of key actors and their roles in policy formulation and execution.
- **SWOT Analysis**: Assessment of strengths, weaknesses, opportunities, and threats associated with policy implementation.

3. RESULTS AND DISCUSSION

3.1. National Policies and Institutional Framework

Nepal's national energy strategy (2013) set broad goals to increase renewable energy supply, enhance energy security, improve efficiency, and ensure affordable energy for all. It explicitly endorsed rural electrification and using hydropower revenues to fund renewable projects, aiming to gradually decrease the share of traditional energy in the energy mix (WECS, 2013). In 2016 the government issued an updated Renewable Energy Subsidy Policy (2073 BS) to replace the 2012 policy. This 2016 policy continued to target poor and remote communities with high subsidies for off-grid renewable technologies but also acknowledged that high subsidy rates may actually be standing in the way of attracting private investment (AEPC, 2016).

In tandem, the Alternative Energy Promotion Centre (AEPC) and development partners launched a National Renewable Energy Framework (2017), an umbrella coordination mechanism to align government and donor programs. The NREF aims to strengthen policy and institutional governance, raise demand for renewables, build local supply capacity, and increase financing for renewable energy (AEPC, 2017). These national policies are overseen by agencies such as the Ministry of Energy (now MoEWRI), the AEPC for off-grid renewables, and the Water and Energy Commission for strategic planning, while the NEA dominates grid development. In 2017 Nepal enacted a new Electricity Regulatory Commission (ERC) to regulate tariffs and sector licensing (NEA, 2018), signaling a shift toward a more structured sector, and the NEA adopted a multi-year corporate development plan to modernize the grid, reduce losses, and prepare for smart metering and digitization.

On the urban side, Nepal's planning documents have gradually incorporated smart and green objectives. The 2017 National Urban Development Strategy frames sustainability under five pillars, one of which explicitly calls for cities to use technologies and land uses that contribute to low carbon emissions and increase the use of alternative energy (MoUD, 2017). The national 15th Plan (2019–2023) set a vision of smart city development, proposing model smart cities and towns, though later reviews noted that tangible progress has lagged (NPC, 2020). In early 2025 Nepal finalized a set of Smart City Indicators, covering smart citizens, economy, governance, and infrastructure, intended to guide municipal planning. So far, however, Nepal lacks a unified smart city law; urban innovation has proceeded through individual city initiatives and donor projects rather than a single national framework.

An overview of key policies and programs is summarized in Table 1. National energy plans (2013 NES, 2016 subsidy policy, 2017 framework) have prioritized rural renewables and grid efficiency. The NEA and donors have launched pilot projects to integrate renewables like World Bank, ADB Grid Solar and Energy Efficiency project launched in 2017, funding the construction of 25 MW of solar plants and advanced distribution-loss reduction in pilot areas (NEA, 2014). Simultaneously, cities like Kathmandu and Pokhara have piloted solar-based smart infrastructure.

Table 4: Major Nepal Renewable Energy and Smart Infrastructure Policies (2013–2025)

Year	Policy/Program	Focus and Scope	Key Points / Source
2013	National Energy Strategy	Long-term energy strategy: boost RE, security, efficiency, rural electrification.	Targets cleaner energy, reduced fossil fuel dependency, and rural electrification (WECS, 2013).
2013	Thirteenth Plan (2013–2016)	Rural RE expansion and grid modernization.	Promotes micro-hydropower (15 MW), solar (6 MW), and wind energy in remote areas (NPC, 2013).
2013	SREP Investment Plan	Scaling RE access via mini-grids and solar.	Aims for 30 MW mini-hydropower and 10 MW solar systems by 2030 (MOF, 2013).
2013	Energy Sector Vision 2050	100% RE transition by 2050.	Prioritizes hydropower (43,000 MW potential) and solar/wind integration (WECS, 2013).
2016	Renewable Energy Subsidy Policy	Revised subsidies for solar, micro-hydro, biogas etc., especially targeting poor and remote communities.	Continues high subsidies for off-grid RETs but notes that high subsidy rates may be standing in the way of attracting private investments; explicitly aligns goals with UN SDGs (AEPC, 2016).
2017	National Renewable Energy Framework	AEPC-led coordination with donors to unify RE programs.	Umbrella plan to strengthen RE governance, grow demand and supply capacity, and mobilize finance (AEPC, 2017).
2019	15th National Plan (2019–23)	5-year development plan (NPC) with urban/smart city goals.	Identifies "smart city" and model urban projects, but reviews note limited concrete achievements so far (NPC, 2020)
2019–23	NEA Corporate Dev. Plan (2019–23)	Utility modernization (loss reduction, smart grid pilot, tariff reform).	Includes preparation for an independent Power Trading Co., smart metering, and adapting to ERC regulation (NEA, 2018).
2020	Smart Metering Road Map (2020–2025)	Nationwide deployment of smart grid technologies.	Targets 5 million smart meters by 2025 to reduce distribution losses (15% → 8%) (ADB, 2018).
2024	Five-Year Roadmap for ERC (2024–2029)	Regulatory strategy and tariff reforms	ERC's strategic plan includes consumer-tariff adjustments (9 % reduction in 2020, further cuts in 2021), new directives/bylaws, enhanced consumer rights, and reliability standards to support smart-grid investment (ERC, 2024).

Source: Compiled by Author

Recent government and development reports show that Nepal has made remarkable progress in expanding electricity access and deploying renewable energy. As of 2024, 99 percent of Nepal's population now has access to electricity, a dramatic increase from just 58 percent in 2015/16 (MOF, 2024). This achievement covers 539 out of 753 local levels being fully electrified, while the remaining areas-mostly remote-are powered by micro-hydropower and solar plants rather than the national grid. Of those with electricity, 97 percent are connected to the national grid, and the rest rely on alternative sources such as micro-hydro and solar (NEA, 2024).

The AEPC had earlier reported that by 2016, about 1.5 million rural households roughly a quarter of the population benefited from alternative energy sources, with installed off-grid micro-hydro capacity reaching around 30 MW and solar PV about 15 MW at that time. Wind energy deployment remained negligible (<0.1 MW). Since then, electrification has accelerated, with the NEA reporting nearly universal coverage by 2024, and ongoing efforts to connect the last remaining unelectrified households, especially in remote and mountainous regions (NEA, 2024).

Despite these advances, challenges remain in ensuring reliable, high-quality electricity, particularly in areas served by off-grid solutions. The government and NEA continue to prioritize quality improvements and grid

integration, aiming to meet the national goal of reliable and sustainable electricity for all within the current fiscal year.

3.2. International Standards and SDGs

Nepal's renewable energy and smart infrastructure policies are closely aligned with international standards, particularly the UN Sustainable Development Goals (SDGs). The 2016 Renewable Energy Subsidy Policy explicitly references SDG 7 and the Sustainable Energy for All initiative, aiming to achieve universal access to clean, reliable, and affordable renewable energy by 2030. This policy framework has led to targeted subsidies, funding mechanisms, and incentives for solar, micro-hydro, and biogas, with a strong emphasis on social inclusion, gender equity, and climate change mitigation (AEPC, 2016).

Urban development strategies also reflect global best practices, as seen in the National Urban Development Strategy, which promotes green cities using low-emission technologies and alternative energy sources, in line with SDG 11's call for sustainable urban environments. Smart-city initiatives in Nepal highlight energy efficiency, renewable integration, and resilient infrastructure, drawing on guidance from the International Energy Agency (IEA) and UN-Habitat. These efforts are supported by programs like the Scaling-Up Renewable Energy Program (SREP), which leverages international financing and technical assistance to expand distributed renewable energy access and modernize urban infrastructure (GON, 2011; MOF, 2013).

Despite strong policy coherence with global recommendations, Nepal faces challenges in implementation, including limited investment capacity, remote populations, and technical constraints. Nevertheless, the country's official frameworks and recent initiatives demonstrate a clear commitment to international sustainability targets, with ongoing reforms to attract private investment, expand rural electrification, and foster resilient, inclusive urban growth.

3.3. Policy Coherence

Nepal's energy and urban policies share broad development goals but often operate in silos. Energy-sector documents are strongly focused on rural electrification and integrating renewables into the national grid and off-grid systems (AEPC, 2016; WECS, 2013). Meanwhile, urban strategies (NUDS, local city plans) emphasize sustainability and service delivery, with only a generic nod to alternative. There is no unified "renewable-smart city" policy. For example, NUDS's "green city" principle urges low carbon technologiesmoud.gov.np, but practical guidance on linking city planning with energy is thin. Similarly, while the 15th Plan envisaged "smart cities," actual mandates and budgets for renewable integration were limited (NPC, 2020). In practice, policy coherence has been mixed: the subsidy policy and NREF align with national goals like SDG7 (Lohani et al., 2023; Zia & Aslam, 2024), but urban infrastructure guidelines seldom reference energy policy (and vice versa) (AEPC, 2016; SDG, 2015). This gap means that, for example, a city master plan might not explicitly incorporate the high-solar potential or EV charging infrastructure into its "smart" strategy, missing an opportunity for synergy.

3.4. Feasibility

The successful incorporation of renewable energy in the smart infrastructure in Nepal depends on a thorough analysis of its practical viability in various facets. Here, the practical implementation feasibility is examined in the technical, financial, and institutional domains. The ability present, constraints, and opportunities within each of these fields are considered and analyzed to determine how well Nepal can develop its renewable-smart infrastructure initiative.

Technical Feasibility

Nepal has proven capabilities in small renewable installations but faces technical constraints at scale. Off-grid solar and micro-hydro technology are established and rapidly deployed, as reflected in over 1.5 million households using RE systems (AEPC, 2016). However, integrating large renewables into the aging grid is challenging. The NEA's transmission/distribution network is old and loss-prone often resulting frequent outages with few automated controls (NEA, 2018). Studies underscore that modern smart grid solutions like advanced metering, automation, demand response are needed to handle Nepal's demand-supply gaps and renewable intermittency (T. N. Bhattarai et al., 2023). Pilot projects like the 25 MW solar project are testing PV integration, but widespread technical upgrades like storage, grid reinforcement, EV infrastructure require time and expertise. The opportunity side is strong as Nepal can make the energy system more efficient through demand-side management and digitization, leveraging falling costs of solar PV and batteries.

Financial Feasibility

Funding constraints have been a persistent obstacle. High subsidies, over 60% for some rural systems have historically crowded out private investment. The 2016 subsidy policy recognized this by planning to reduce subsidy rates over time. Nepal has therefore created new finance mechanisms e.g. the Central Renewable Energy Fund (CREF) to mobilize credit for renewables. In practice, large-scale renewable smart projects have relied on international aid of ADB, World Bank and others have funded major grid and street-lighting projects (AEPC, 2024). Thus far Nepal has not mobilized significant private capital for renewables or smart infra domestically; local banks offer only small loans, and the consumer tariff especially lifeline rates cover limited cost. In summary, financial feasibility hinges on sustained external funding and better subsidy/credit designs; current efforts (NREF, CREF) aim to improve financing, but overall investment needs for generation and smart grids far exceed domestic budgets.

Institutional Feasibility

Nepali governance is still in transition. The 2015 Constitution devolved powers to provinces and municipalities, complicating energy and infrastructure planning. For example, newly formed local governments seek mandates e.g. cities handling local streetlights, but the legal and funding frameworks are still being defined. The creation of the ERC (2017) is a major shift as the NEA must now adapt to regulation and transparent tariff setting (ERC, 2024). This transitional phase has seen some confusion, NEA's monopoly SCOT analysis notes that it still builds new hydros in a regulated environment. In the urban sector, inter-ministerial coordination is limited, Ministries of Energy and Urban Development have separate agendas. International frameworks try to align agencies like AEPC and NREF, but capacity gaps remain due to weak project management, procurement, monitoring (AEPC, 2024; Raihan et al., 2024). On the positive side, some institutions are building expertise like NEA's own plan includes training for smart grid operations, and KMC has created a Smart City Cell for coordinating ICT projects (A. P. Adhikari & Bhattarai, 2021; NEA, 2018). Overall, institutional feasibility is mixed structures exist but must become more integrated, and ongoing federal reforms add uncertainty.

3.5. Stakeholder Roles and Dynamics

Multiple stakeholders shape Nepal's renewable smart sector. Government bodies like MoEWRI, Ministry of Urban Development, local governments set policy and operate infrastructure NEA. The AEPC is a key implementation agency for rural renewables. Donors and development banks like ADB, World Bank, GEF/GCF, JICA, etc. play an outsized role, funding infrastructure projects and capacity building (Dahal, 2023). Private sector participation is growing slowly. Communities and consumers have been engaged through co-ops in villages with mini-hydro and user committees responsible for managing streetlights. Non-governmental organizations and academic institutions also contribute to planning and awareness for locals regarding smart and green cities workshops (Dixit & Shaw, 2023). In short, stakeholder dynamics are complex, projects often succeed where public, private and community interests align, but lack of clear incentives or communication can stall initiatives. Improving cross sector dialogue between city planners and the power authority will be key to scaling up integration.

3.6. SWOT Analysis

Drawing on the above, we assess Nepal's policy environment for renewable-smart infrastructure:

Strengths

Nepal is richly endowed with renewable resources hydropower, solar, biomass and a clear high-level commitment to clean energy. The NEA has a nationwide customer base and monopoly power to coordinate efforts. International support is strong with policies explicitly link to SDGs (AEPC, 2016), and donors remain eager to fund renewable/smart projects. The nation's small hydro and solar industries have gained local expertise like cooperatives, installers for decentralized projects.

Weaknesses

Infrastructure is a major constraint, the grid is inefficient with high losses and poor rural reach (Sarangi et al., 2014). Energy policies have historically relied on heavy subsidies that discourage private investment. Institutional capacity is limited; NEA's own plan notes weak project management and lack of data systems. There is a policy gap between energy and urban sectors. Financial resources are tight Nepal's public debt and

fiscal limits mean large projects depend on donors (U. Bhattarai et al., 2023, 2024). These weaknesses hamper the implementation of integrated renewable-smart solutions.

Opportunities

There is substantial upside for Nepal. Technological advances like cheaper solar panels, batteries, smart grids can reduce costs and address intermittency (T. N. Bhattarai et al., 2023). Nepal could become a regional power exporter in dry seasons, increasing revenues. Demand growth, including comfort and electrified transport, will expand markets for renewables. Global climate financing mechanisms can be tapped, Nepal already won ADB/SCF funding for solar. Digitization and energy management tools e.g. smart meters, and demand-response software offer a path to system efficiency. Finally, Nepal's transition to federalism could spur innovation at the local level like provincial solar parks, if governance is well managed (D. R. Adhikari et al., 2024; Bhatt & Joshi, 2024).

Threats

Several external and internal threats loom. Climate change poses risk erratic monsoon flows could jeopardize hydropower and flood infrastructure (Karki, 2024; Samjhana & Manan, 2025). Political and bureaucratic delays are frequent, NEA cites pending new regulations (ERC, taxation issues) and resettlement disputes as project blockers. There is also a missing demand threat, if urban growth stalls or COVID-19 impacts continue, economic crisis, planned projects may be underused as the NEA notes excess capacity as a risk. Currency fluctuations and potential trade barriers with India could affect equipment imports and future power exports. Finally, rising off-grid and distributed generation like rooftop solar, home battery systems could reduce NEA's revenue base, complicating financing for large-scale infrastructure (D. R. Adhikari et al., 2024b; Ghimire & Kim, 2018).

4. CONCLUSION AND POLICY IMPLICATIONS

In summary, Nepal has made significant progress in policy and small-scale implementation of renewable smart infrastructure over the last decade. National strategies and frameworks clearly prioritize clean energy access and rural electrification, in line with SDG7. However, tangible integration of renewables into smart city development is still limited by technical, financial, and institutional hurdles. The energy and infrastructure sectors have yet to fully harmonize their efforts; many projects remain pilot-scale with donor support rather than self-sustaining city-led programs. Nepal's recent push to define smart-city indicators and its ambitious targets reflect a positive vision but achieving these will require strengthening grid and ICT infrastructure, reforming subsidy/finance schemes, and better coordinating among agencies. Our thematic analysis underscores that addressing policy fragmentation by enhancing coherence between energy and urban policy, improving capacity for smart-grid tech and project management, and mobilizing diverse stakeholders i.e. government at all levels, private investors, communities are crucial next steps.

In conclusion, Nepal's renewable-smart infrastructure trajectory shows promise but also clear gaps. Over the next decade, Nepal will need to leverage its renewable resources, secure financing, and build robust institutions to realize the promise of smart, sustainable cities. Success will hinge on maintaining policy momentum, adapting to new technologies, and ensuring that energy planning is fully integrated with urban development. With its strong commitment on paper and early pilot successes, Nepal is poised to make further advances provided it can overcome the practical challenges identified above.

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