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Evaluating four decades of energy policy evolution for sustainable development of a South Asian country—Nepal: A comprehensive review

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Abstract

In this study, we assessed the accomplishments and shortcomings of an exhaustive collection of energy policies of Nepal over four decades, using a five-dimensional energy security framework (availability, affordability, technology, sustainability and governance) for sustainable development. We adopted a mixed-method approach involving thorough review of 70 policy documents (1984–2022), systematic review of 86 peer-reviewed journal articles on Nepal's energy policy, and consultations with 11 experts. Our evaluation shows that while there is a progressive trend, Nepal's energy policies face challenges of political instability, governance issues, siloed development practices, lagging research and development, inefficient energy demand management, and heavy reliance on international support. Additionally, we offer four tailored recommendations for the related stakeholders: supply-side management, demand-side management, multi-sector collaboration, and political stability and good governance. The insights and recommendations we provide have significant regional implications, particularly in the context of potential cross-border clean electricity sharing in South Asia.

KEYWORDS
energy policy, energy security framework, mixed-method, review, South Asia, sustainable development

1 | INTRODUCTION

Energy is a nation's building block as well as a gauge to measure its development (Adedoyin et al., 2020; Saidi & Hammami, 2015). Moreover, economic development and energy consumption have a bi-directional cyclic relationship (Chen, Mamon, et al., 2023; Devkota et al., 2022; Mohsin et al., 2021). Therefore, sustainable development needs to holistically consider economic progress, social evolution and environmental safeguarding (Safi et al., 2023). However, developing countries are lagging behind in their development feats, energy being one of the most impacted sectors (Dominguez et al., 2021; Fadly, 2019; Gebreslassie et al., 2022). Equally important, but generally overlooked in these regions, are policies (Aryal et al., 2021; Hartono et al., 2023; Laudari et al., 2020; Maraseni et al., 2019). An effective policy analysis requires a framework that considers multiple objectives, sectors, dynamic interdependencies, uncertainties, and unquantifiable impacts (Heazle & Pillar, 2012). Studies such as Tidwell and Tidwell (2018) build on 'sociotechnical imaginaries' and

Wittmayer et al. (2022) on 'social innovation' to emphasize the need for valuing the general public in policy making instead of only sectoral experts, state and international interventions. Concepts of 'policy paradigms' have been popular in assessing the ways policymakers' ideas are translated into policies through the institutions they represent (Zittoun, 2015).

Although the implementation of policies follows a top-down approach, their formulation and regular revisions ideally require bottom-up trajectories to achieve the desired targets (Pandey & Sharma, 2021; Wu, 2020). Timely incorporating changes in the national level policies concurrent with the global and regional development allows for assessing and reacting to the contemporary needs for national benefits. Iconic studies such as Hall (1993) conceptualized how polices change with the help of *orders* ('first', 'second' and 'third'), in terms of the magnitude of their change. Similarly, some researchers have defined the *mechanisms* of policy change occurrence ('cyclical', 'dialectic', 'linear' and 'teleological') (Capano & Howlett, 2009) while some explain the different *modes* of change (such as 'layering', 'drift' and 'conversion') that policies undergo over a time period (Vij et al., 2018). Scholars have used the notion of 'energy imaginaries' and 'transnational assemblages' to explore how energy aid interventions and bilateral relations are responsible for the changes in policy and implementation levels (Movik & Allouche, 2020). No matter which order, mechanism or mode the change follows, policies are usually guided by public demands. In the case of the global north, people are generally well aware of their rights and needs and are actively involved in policy making (for example as shown by Hill & Connelly, 2018; Johnstone et al., 2020; Sattler et al., 2018; and Borozan, 2022). However, the case is usually different for the global south where illiteracy and unawareness among the general public are dominant leading to striking global north–south disparities in the energy sector and policy making process (Abbas et al., 2022; Lohani et al., 2023; Mittal, 2022; Shakya, Adhikari, et al., 2022; Weko & Goldthau, 2022).

Studies have investigated the varying roles of multiple actors in the policy making process. The influential groups, consisting mostly of politicians and elites, senior bureaucrats, with active involvement of non-government organizations and donors generally influence the public policies in the developing world (Aryal et al., 2021; Vij et al., 2018). Involvement of civil societies, private sector and general public to an extent of persuasion is rather theoretical (Liao et al., 2021; Pandey & Sharma, 2021), although legitimacy of the policies comes through the parliament (which is considered "for the people and by the people"). This leads to delaying of the development activities, which in turn increases the disparity among rich and poor (Hashemi, 2021; Vanegas Cantarero, 2020): it becomes a vicious cycle. Moreover, innovative policies through 'constructive technology assessment', 'responsible research and innovation', and 'transformative change' have been proposed by scholars (Sovacool et al., 2020).

Researchers have explained energy as an indispensable resource for overall development and stress the need for focusing on accessibility and efficiency considering the heterogeneity in supply and demand (Verma et al., 2024). Moreover, the 'energy ladder' hypothesis assumes that as the economic condition gets better, people tend to switch to modern and efficient energy technologies from traditional sources (Dominguez et al., 2021). Recent studies (for example, Sofian et al., 2024) have shown immense possibilities of renewable energy technologies, particularly solar and wind in fulfilling global energy demands and sustainable goals. However, scholars also illustrate the necessity to go beyond solar and wind into other renewables for a sustainable future (Rastegar et al., 2024). Taking the case of developed countries, Pi et al. (2024) not only showed that energy efficiency has a leading role in attaining environmental sustainability but also highlighted the importance of green energy policies to ensure sustainable development. Interestingly, Fan et al. (2024) revealed a strong relationship between energy poverty and health, the vulnerability being higher in the developed countries. Likewise, Adebayo and Ullah (2024) demonstrated the necessity to adopt comprehensive approaches to prioritize energy efficiency, increase use of renewable energy in the generation mix and enhance sustainable urbanization to achieve sustainable development in Sweden. Adha et al. 2024) assessed the dynamic impact of energy efficiency on economic growth and pointed out high levels of energy inefficiencies currently existing in the ASEAN region. Furthermore, Gautam and Bolia (2024) presented the adoption of electric vehicles as a promising intervention for sustainable urban development in India. Similarly, post-COVID studies have shown that energy efficiency measures through technological advancements, supportive policies and collaborative actions have a huge potential for sustainable and resilient energy future (Gorina et al., 2024; Pinczynski et al., 2024). Moreover, collaborative efforts from different sectors of the economy are crucial for achieving energy security and ultimately leading to sustainable development. Hence, we build upon the notion that sustainable development is achieved through combined actions across multiple disciplines (Ruan et al., 2024), among which energy policies play an integral role.

In this paper, we examine the dynamics of energy policies of Nepal — a land-locked developing country in south Asia — during the last four decades. Nepal has been struggling to meet the increasing energy demands through traditional fuels, imported fossil fuels and power rationing (MoF/GoN, 2023; NEA, 2023; WECS/GoN, 2023). As Movik and Allouche (2020) mention, Nepal has had to go through a 'chaotic fragmentation of the energy landscape'. Shakya, Bajracharya, et al. (2022) further point out the role of diesel generated electricity, in substantiating the supply of grid electricity in the commercial areas of Nepal but at the cost of immense fuel import expenses, high levels of air pollution leading to health hazards, adverse impacts on the crops and the overall environment in the absence of amicable policy settings. Aryal et al. (2023) demonstrated integrating end-use electrification and cross-border electricity trade could be highly beneficial from the energy security, environment and financial perspective of Nepal and recommend enabling supportive energy policies. However, there is limited research in Nepal providing policy inputs to the energy sector (NEO22, 2022). There are some studies which explore energy poverty in the developing countries (such as Abbas et al., 2022; Haldar et al., 2023; Shakya, Adhikari, et al., 2022), and cross-border energy/electricity trade possibilities in the South Asian region, for example by Huda and McDonald (2016), Hussain et al. (2019), Mittal (2022) and Saklani et al. (2020). These publications touch upon some aspects of policies, for instance the socio-hydrology by Jaramillo et al. (2018); people's perceptions of energy technologies (Bhattarai, Maraseni, Devkota, & Apan, 2023; Shrestha, Jirakiattikul, Lohani, & Shrestha, 2023); econometrics of energy by Parajuli et al. (2014) and Pokharel (2007); preference of fuels by Koirala and Acharya (2022) and Joshi and Bohara (2017); willingness-to-pay for cooking fuels by Das et al. (2022); power and politics by Suhardiman et al. (2014); pollution and environmental implications related to energy consumption by Raihan and Tuspekova (2022), Sharma and Shrestha (2023), and Shrestha and Dhakal (2019); issues of gender equality and social inclusion in energy policies (Buchy & Shakya, 2023; Khadka et al., 2024); possible co-benefits of demand side management with microgrids of diesel generators and solar PV for energy security (Shakya, Bajracharya, et al., 2022); climate change by Suman (2021); ethnicity/caste-based differentiation in household energy (Nepal et al., 2023; Rahut et al., 2022); and ineffectiveness of donations and subsidies in the energy sector by Bhattarai, Maraseni, Apan, and Devkota (2023). These all follow a piecemeal approach, which have missed portraying the larger picture and therefore have limited policy implications. Furthermore, Baniya et al. (2021) highlights the lack of country-specific studies on policy changes, particularly in the Global South. Moreover, trailing the entire energy development pathway of Nepal over a substantial time-window with a comprehensive holistic "socio-technological perspective" of policy assessments and implications is missing. We aim to address this much needed research gap.

Hence, the overarching objective of this study is to critically examine the energy related polices of Nepal over the last four decades. Specifically, we focus on the following:

1. Synthesizing the progression, achievement, and limitations of the examined policies
2. Identifying current challenges and providing a way forward for sustainable energy future of Nepal

We evaluated the performance of different energy policies developed over time based on the energy security framework encompassing five broad dimensions (availability, affordability, technology development, sustainability and governance) prescribed by Sovacool and Mukherjee (2011). A mixed method of literature review and expert consultations was adopted.

To the knowledge of the authors, this is the first study carrying out such a comprehensive review of policy documents related to the energy sector of Nepal over the last four decades (1984–2022). Therefore, we have two distinct contributions from this study. First, Nepal is one of the least energy consuming (MoF/GoN, 2021) and carbon emitting countries in the world (WB, 2024). Although the current emissions are very less, with future economic development, a sharp increase in energy use and associated emissions can be expected for Nepal. However, studies have shown that the current fuel consumption pattern of Nepal is unsustainable (NEO22, 2022). Hence, this will be a timely study in orienting Nepal's energy development towards a direction that is sustainable. Second, this paper is a significant addition to the energy scholarship of South Asia, in general and Nepal, in particular. Interestingly, a recent study shows that two-thirds of the untapped global hydropower potential is in the Himalayas (Xu et al., 2023) among which Nepal has a significant contribution possibility (Gyanwali et al., 2020; Zou et al., 2022). Moreover, past studies on hydropower development in Nepal with future cross-border electricity trade prospects are encouraging (SARI/EI-IRADe, 2021; SARI/EI/IRADe, 2018; SARI/EI, 2020; Hussain et al., 2019). Therefore, the analysis and recommendations we provide can have regional level significance because of the common socioeconomic, physiographic and political settings across the neighboring countries, particularly for regional energy sharing.

2 | METHODOLOGY

2.1 | Study area

Nepal is a mountainous country situated between India and China (Figure 1): two largest growing economies of the world. Nepal has a very small economy with a GDP of 41.39 billion USD (FY 2022/23) (MoF/GoN, 2023), which is about 1% of South Asia and 0.04% of the world values (WB, 2024). The total annual energy consumption of the country was 14.943 million tons of oil equivalent (toe) in the fiscal year 2022/2023 (WECS/GoN, 2023). Moreover, annual electricity consumption of Nepal was 6789 GWh with a peak demand of 1870 MW (MoF/GoN, 2023; NEA/GoN, 2023). The largest electricity consuming sector was residential (36.6%, 2485 GWh) followed by the industrial sector (30.7%, 2084 GWh) (MoF/GoN, 2023). The total installed power capacity of the country stands at 2666 MW until the end of the FY 2022/23, out of which, 2449 MW is generated from large hydroelectric projects, 75 MW from solar, 53.4 MW from thermal 82 MW from smaller renewable technologies and 6 MW through co-generation technologies from sugar mills (MoF/GoN, 2023).

2.2 | Theoretical background

In this study, we have adopted a comprehensive energy security assessment framework by Sovacool and Mukherjee (2011) to examine the energy policy arena of Nepal. This theory has evolved over time (Sovacool, 2012) and its multiple variants have been used by scholars for different research needs. For example, Sovacool (2013) presented the energy security of a country as an interconnection of availability, affordability, efficiency, sustainability and governance in presenting the case of 18 countries; Narula (2013) assessed four dimensions: availability, acceptability, affordability and efficiency to quantify energy security of India; GIZ (2013) examined the pattern of household fuel usage of eight developing countries using aspects of accessibility, affordability and acceptability; Islar et al. (2017) applied the energy-justice-framework to examine some specific rural energy

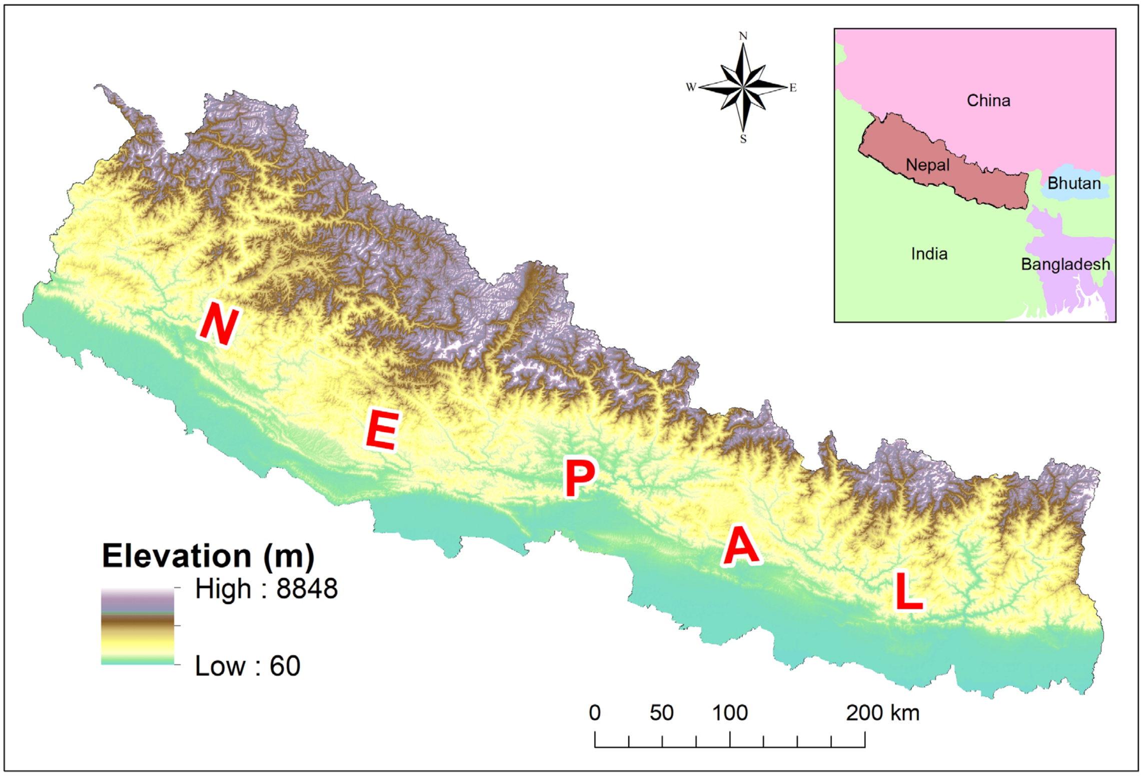

FIGURE 1 Geographical setting of Nepal.

policies in Nepal; and the 4-A (availability, applicability, acceptability, affordability) framework was applied by Malik et al. (2020) for assessing energy security of Pakistan. However, we have chosen the fundamental version of the framework in our case for holistically analyzing the entire energy policy sector of Nepal and providing an unbiased overview of its progression, achievements and limitations. Adapted from Sovacool and Mukherjee (2011), we list below the five dimensions that form the core of our study:

i. *Availability*: This dimension deals with sufficiency and security of energy for all. It further looks into diversification of the energy mix promoting energy sources available domestically.
ii. *Affordability*: This dimension is associated with concerns of generating energy at the lowest cost, enabling equitable access to energy for all, whether rich or poor. It also deals with transparency in pricing and predictability of energy and fuels.
iii. *Technology*: This dimension considers the capacity of the nation to adapt to changing technologies and increasing energy efficiency maintaining high levels of safety, reliability, resilience, investment and employment. It is also associated with research and innovation in energy technologies for achieving better energy efficiency.
iv. *Sustainability*: This dimension is concerned with the environmental and social sustainability of the energy sector. It is also related to concerns of climate change and its mitigation and adaptation.
v. *Governance*: This dimension focuses on principles of rule of law and human rights leading to good governance by emphasizing participatory modes in energy development. It further deals with institutionalization, accountability towards the people, legitimacy of the activities, geopolitics, competition and national/international markets in addition to community level knowledge enhancement.

2.3 | Methods

Mix-methods have been a popular choice among researchers for policy analysis. For instance, Sovacool and Mukherjee (2011) adopted a mix-method approach to develop a practical framework for assessment of energy security with global applicability. Likewise, Movik and Allouche (2020) used mixed-methods approach to examine the historical roles of foreign aid in the energy sector development of low-income countries such as Nepal. A similar method was used by Aryal et al. (2021) for discussing the actors shaping the environmental policy, and by Laudari et al. (2020) for assessing the policy and institutional shifts in Nepal's forestry policy regime. Likewise, Bhattarai et al. (2021) adopted a mix method to analyze ecosystem-based adaptation policies while Pandey and Sharma (2021) implemented a similar process to assess the climate resilient development of Nepal. Therefore, we have adopted a mix-method of literature review and expert consultation for this research. Mix-methods bear high significance as there are a limited number of publications in the energy sector of Nepal and therefore, knowledge shared by experts are extremely important. The workflow of our study is presented in Figure 2 and the methodological steps are explained in the following sections.

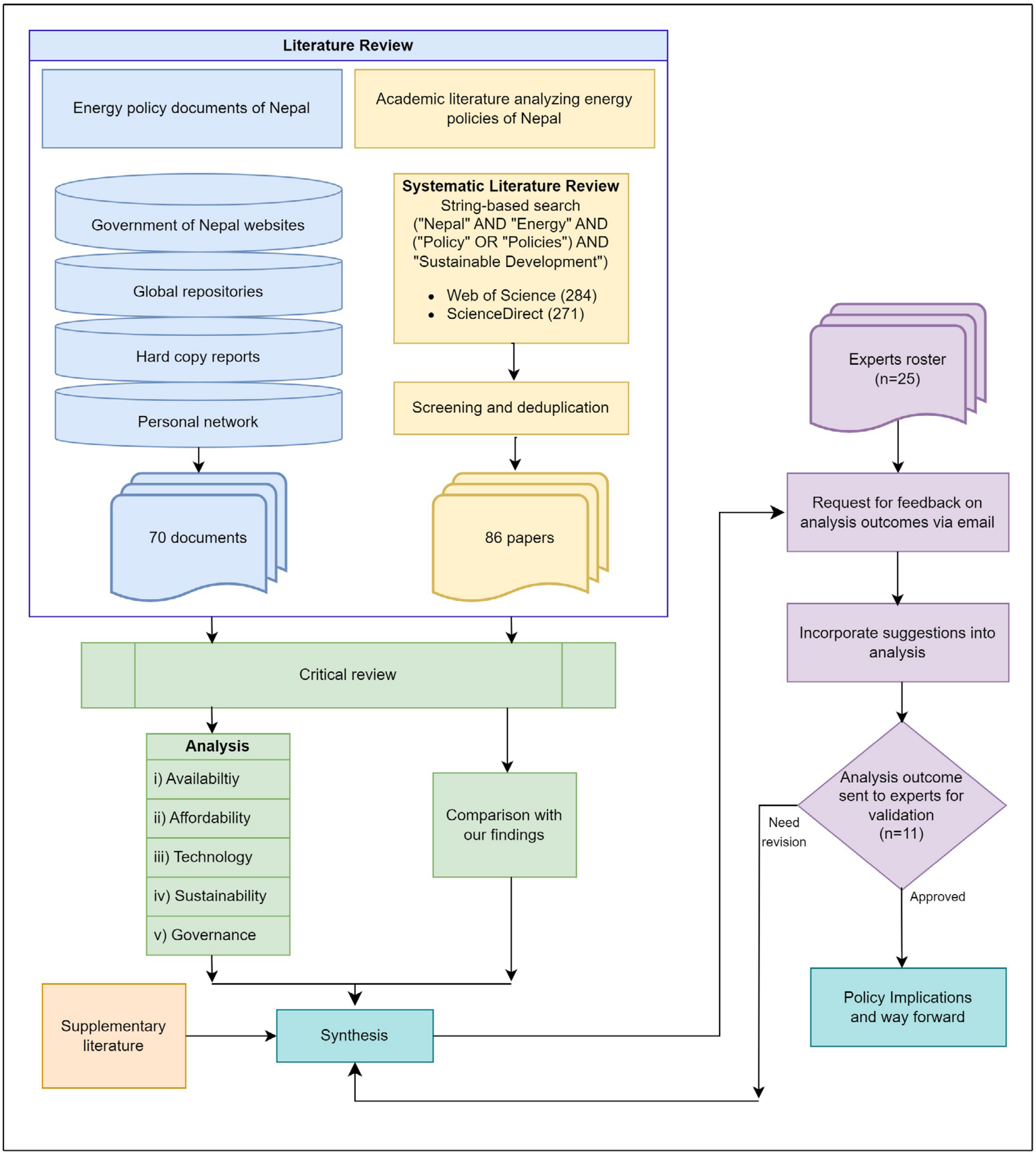

FIGURE 2 Methodological flow diagram.

Literature review consisted of two parts. First, we acquired all the policy documents related to the energy sector of Nepal from 1984 to 2022 through online sources of the Government of Nepal (GoN), international repositories, hard copy reports from the concerned ministries/departments, and through personal networks of the authors who have a considerable experience working in the energy and natural resources sectors of Nepal. For a document to be considered in our list, it should contain at least one statement/clause (or sub-clause) related to energy. This led to the compilation of an exhaustive set of 70 policy documents (listed in Tables A1 and A2; chronological progression presented in Section 3.1). The strengths and achievements of all these policy documents were qualitatively evaluated.

The systematic literature review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) framework (Moher et al., 2010; Rethlefsen et al., 2021). This framework is mostly used in engineering, environment, physical and social sciences (Adeyinka-Ojo, 2016; Adhikari et al., 2024). *ScienceDirect* and *Web of Science* databases have an exhaustive collection of scientific articles published across different disciplines. Moreover, high quality research articles from both open-access and subscription modes are indexed in these databases (Azril et al., 2018). The application of these databases has been recommended by many researchers carrying out systematic literature review (for instance, Aryal et al. (2022) in forestry; Adhikari et al. (2024) and Bhattarai, Maraseni, and Apan (2022) in renewable energy; Bibri (2021) in engineering and infrastructure development; Budhathoki et al. (2024) in agriculture; Maina et al. (2021) in medicine; Hoffmann et al. (2020) in environmental science; and McKeown and Mir (2021) in data science, among others). Our search included published peer-reviewed (original and review) articles in English, excluding books and book series, conference proceedings, editorials, letters, patents, working reports and research notes. Moreover, peer-reviewed journals maintain the scientific credibility and high level of quality of their published papers (Bhattarai, Maraseni, & Apan, 2022). In our search, the first level keyword search yielded 6745 hits from *ScienceDirect* and 503 from *Web of Science* databases, respectively. The title-abstract-keyword level refining led to 284 and 271 articles from the two databases, respectively (Figure 2). The list was further manually screened based on whether they discussed policies and relevancy to our paper through abstract level reading. This list was imported to *EndNote* (in *.ris* format) and deduplication was carried out using the freely available online tool—*IEBH Systematic Review Accelerator* (https://www.sr-accelerator.com/#/) leading to the final retention of 86 articles (Supplementary Material S2) which were reviewed in entirety. Additionally, the study was supplemented by other publications providing significant inputs to our review and discussion. Data extraction from the reviewed publications and analysis were carried out applying statistical and visualization tools in *MS-Excel*. Qualitative investigation was done manually based on judgment and the experience of the authors and bolstered by expert interviews.

The next step consisted of identifying a roster of high-level Nepalese experts who are abreast with the overall energy development of Nepal. After extensive research and series of consultations with key informants, a list of 25 experts from Nepal consisting of academicians, senior government officials (bureaucrats and technocrats, in-service and retired), senior experts from the private sector (mainly NGOs and INGOs) and senior practitioners was developed. The criteria for inclusion in our roster were: (i) the expert had to be well acquainted with energy development in Nepal; and (ii) the expert had to have a professional career of at least 15 years in this field. We shared the preliminary results of our review with all the identified experts through email during December 2022 to February 2023 requesting them for their critical feedback on different aspects through a questionnaire (Supplementary Material S1). This expert consultation was carried out adhering to the Human Ethics Approval (HREC ID H22REA258) from the University of Southern Queensland, Australia. However, only 17 experts got back out of the 25 whom we had reached out to. Among them, six did not provide specific feedback. Hence, we considered the critical comments from 11 experts (Supplementary Material S3). After incorporating their suggestions into our analysis, we further shared our findings with them a second time for validation.

3 | RESULTS

3.1 | Chronological progression of energy policies

A progressive trend can be seen in the number of energy related policies that have been formulated in Nepal over the last four decades (Figures 3, 4). Additional details of their sectoral coverage, technologies, legal arrangements, research focus, promotion of private sector and international collaboration, and organizations involved in the preparation of these documents are presented in Table A1. Interestingly, a direct correlation can be seen in the cumulative number of policies and electricity development trend in the last four decades with 486 GWh in 1986 to 12,369 GWh in 2023 (Figure 3). Although a sharp demarcation is difficult, it can be seen that Nepal's energy sector has broadly evolved through six distinct periods continuously building on the achievements of the preceding ones. These six epochs are discussed below.

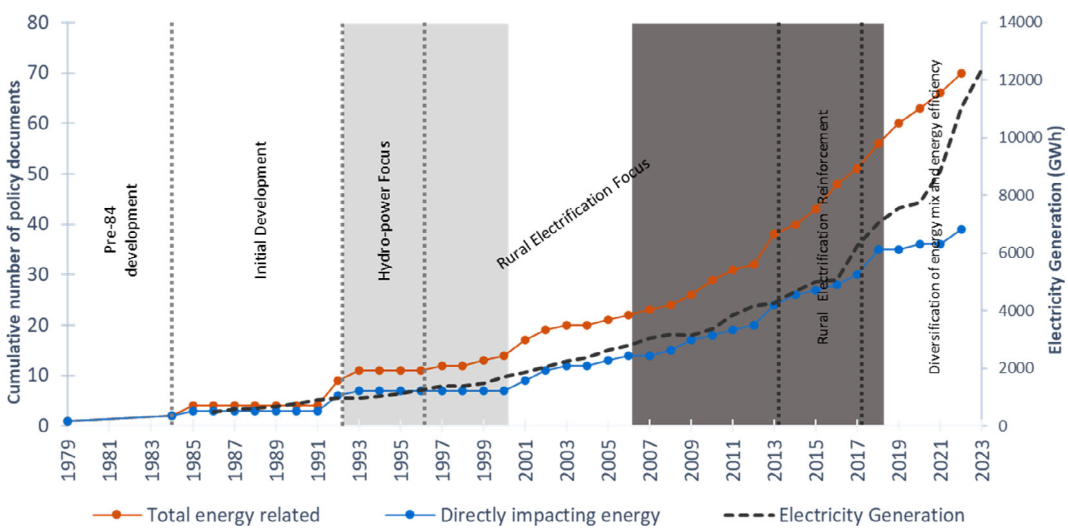

FIGURE 3 Progression of energy related policies and electricity generation in Nepal split into six epochs (shown by the dotted vertical lines). Shaded blocks represent years with electricity 'loadshedding'. The epoch 2006–2018 (dark gray) had up to 16 h while 1992–2000 (light gray) had lesser number of hours of loadshedding daily.

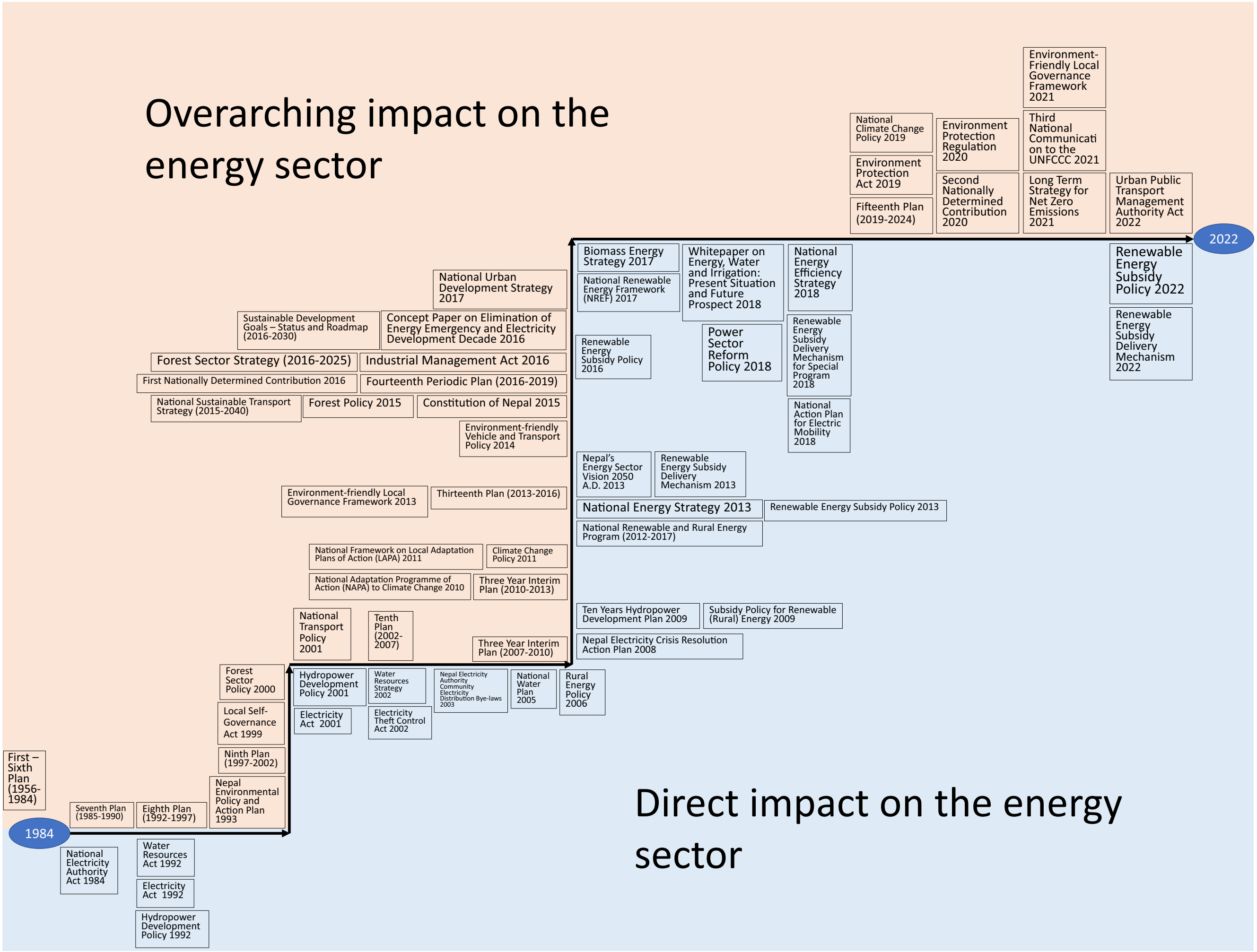

FIGURE 4 Timeline of policies in Nepal from 1984 to 2022 which are directly related to (light blue background) or have overarching impacts (light brown background) on the energy sector.

(i) Pre-84 development: Nepal has always been dependent on traditional agriculture-based fuels for meeting its energy demands. Interestingly, people in Nepal have used hydropower for centuries mainly for milling and grinding grains. The country had a head start in hydroelectricity generation with the first hydro-project (500 kW Pharping Hydropower Plant) commissioned in 1911 (Sharma & Awal, 2013). It was one of the earliest hydropower development projects in Asia. Unfortunately, Nepal could not maintain this momentum. The project was constructed by the Rana rulers during that time for supplying electricity to their Singhadurbar palace located in the centre of the capital city Kathmandu. The general public had no access to this electricity. The second hydropower plant (600 kW Sundarijal) was built in 1934. Only after the construction of the 2.4 MW Panauti project in 1965, electricity became accessible for public use. There were few additions to the hydropower fleet until the early 1980s and the installed capacity of the country became 120 MW (Sharma & Awal, 2013). This period can be considered an elite- and capital-centered development of the energy (mainly electricity) sector.

(ii) Initial development (1984–1992): From the energy standpoint, the Nepal Electricity Authority Act 1984 can be considered a first milestone for modern Nepal. Although the Gandaki River Basin Power Study was conducted in 1979, the plan was not immediately materialized. The Nepal Electricity Act 1984 provisioned the establishment of the Nepal Electricity Authority (NEA, previously functioning as National Electricity Department) to make arrangements for efficient and reliable electricity generation and distribution throughout the country. The Seventh (1985) and Eighth National Plans (1992) envisioned hydropower development and research on water resources and energy. Alternative energy was introduced in the national policy framework instigating policies for micro-hydro, biogas, solar and wind technologies. Improvements in cooking stoves, small water turbines and water mills by providing subsidies and credit facilities were also provisioned.

(iii) Hydropower focus (1992–1996): The Electricity Act 1992 focused on the management of electricity with licensing arrangements. Endorsement of the Hydropower Development Policy 1992 by the Electricity Act 1992 can be considered another milestone. This

policy promoted hydropower (large and small) development for meeting industrial, domestic and transportation demands as well as envisioned national and foreign investment in hydropower. The Nepal Water Resources Act 1992 made licensing provisions for the use of water resources and provisioned the formation of water users groups for the purpose of generating micro-hydro schemes. The Nepal Environmental Policy and Action Plan 1993 recommended optimum utilization of water resources by implementing multi-purpose hydropower projects by promoting rural electrification and minimizing the environmental impacts. Unfortunately, NEA reported technical issues at the Kulekhani Hydropower Project (Nepal's only storage type project till date), because of which the country had to face several hours enforced routine power cuts (popularly known as “loadshedding” in Nepal) in designated areas from 1992 (shown by the light gray block in Figure 3) (NEA/GoN, 1993). Moreover, ‘loadshedding’ was there to stay for long (Shrestha, 2010).

(iv) Rural electrification focus (1996–2013): The establishment of Alternative Energy Promotion Centre (AEPC) in 1996 marked a milestone in promoting rural energy and alternative energy technologies in Nepal. The Local Self-Governance Act 1999 granted power to the local authorities for mini- and micro-hydropower projects. The electricity generation and demand deficit kept on rising until 2000 which saw the temporary uplifting of loadshedding in Nepal. The 2001 revision of the Hydropower Development Policy, through the Electricity Act 2001, focused on cost minimization, institutional restructuring, demand side management, and rural electrification. The Water Resources Strategy 2002 set short term (5-years), medium term (15-years) and long term (25-years) targets for meeting the country's energy needs. The Tenth Plan 2002 established the Rural Energy Fund (REF) for local-level mobilization. After a temporary relief of a few years, Nepal was again forced to face ‘loadshedding’ from 2006 onwards (left edge of the dark gray block in Figure 3). The Rural Energy Policy 2006 conceptualized expanding REF to the Central Rural Energy Fund (CREF), emphasized private sector involvement, capital subsidization, and research and development (R&D) in rural energy technologies. Energy poverty reduction has been emphasized by recent studies such as Subedi et al. (2023) and Lohani et al. (2023). The Nepal Electricity Crisis Resolution Action Plan 2008 was targeted at addressing the electricity crisis through short-term and long-term approaches including increase of power imports from India, construction of thermal power plants, expansion of transmission capacity and the prevention of electricity theft. The Subsidy Policy for Renewable Energy 2009 aimed to decrease the rural–urban energy access gap. It further recommended establishing a task force to draft a plan to produce an extra 10,000 MW of hydropower within the next decade. The Energy Sector Synopsis Report 2010 recommended sustainable expansion of energy generation options.

(v) Rural electrification reinforcement (2013–2017): The Nepal's Energy Sector Vision 2050 A.D. 2013 identified hydropower as the leading sector to meet the country's energy needs in the domestic, industrial, commercial and transportation sectors. Recommendations included diversifying the energy generation mix with improved cooking stoves, sustainable use of firewood, and connecting isolated renewable energy systems (mainly from the rural areas) to the national grid (Shakya et al., 2023; Thapa et al., 2021). Some institutional restructuring focused on hydropower and electricity development was also carried out during the 2010s. The Thirteenth Plan 2013 promoted R&D in renewable energy, operationalized the CREF, and encouraged solar, wind, and hybrid technologies for irrigation and domestic water supply. The National Energy Strategy in 2013 aimed to promote new transport technologies such as fuel blending, electric and hybrid vehicles. The Renewable Energy Subsidy Policy 2013 focused on inclusive and accessible subsidies for non-electrification (solar thermal systems, institutional and rural community solar water systems, biogas, biomass and improved water mill) and rural electrification (via off-grid solar home systems, small- and micro-hydropower, wind energy and electricity from biomass energy) (Adhikari et al., 2024; Shakya, Adhikari, et al., 2022; Thapa et al., 2021). The Renewable Energy Subsidy Policy in 2016 targeted a shift from subsidies to credits for rural areas, aligned with UN's SDG7 and the Sustainable Energy for All initiatives by 2030. Lohani et al. (2023) and Bhattarai, Devkota, Maraseni, et al. (2023) underscored the multi-disciplinary benefits of renewable energy to SDGs for Nepal. The policy also strengthened CREF for credit mobilization and revised subsidy rates based on various factors including technology type, cost, capacity, geographical location and targeted beneficiaries. Several such aspects of renewable energy sector policies of Nepal have been highlighted by researchers, for example by Lohani et al. (2023) and Sanjel and Baral (2019).

(vi) Diversification of energy mix and energy efficiency (2017 onwards): The National Renewable Energy Framework (NREF) 2017 is a cornerstone policy in Nepal that emphasizes renewable energy technology for diversifying the energy generation mix as well as increasing the energy efficiency. Jointly owned by the government and development partners, the NREF focuses on strengthening local capacity, transitioning from subsidies to credit-focused financial models, and promoting collaboration between research institutions and the private sector. The Biomass Energy Strategy 2017 aims to generate energy from agri- and forest-residues and organic wastes, partially replacing diesel and petrol with bio-diesel and bio-ethanol. It also targets making Nepal indoor pollution-free by 2022 by ensuring clean cooking technologies and in all households by 2030. The Whitepaper on Energy, Water, and Irrigation: Present Situation and Future Prospect 2018 (Whitepaper) sets ambitious targets for hydropower development and envisions concepts of replacing domestic, transport, industrial and commercial fuels by electricity through implementation of new technologies such as net-metering, tariff revision based on time and season, diversifying energy generation mix including peaking run-of-river, pumped hydropower and other alternatives. Additionally, encouraging cross-border power transfer and integrated development of transmission lines and roads has been recommended by studies (Sanjel & Baral, 2020; SARI/EI, 2021).

The National Energy Efficiency Strategy 2018 introduces initiatives for increasing energy efficiency and sets goals for 2030, including the development of national standards and a National Energy Efficiency Action Plan for institutionalizing energy efficiency. The Renewable Energy Subsidy Delivery Mechanism for Special Program 2018 facilitates off-grid solar schemes, solar lighting in religious places, solar pumps for

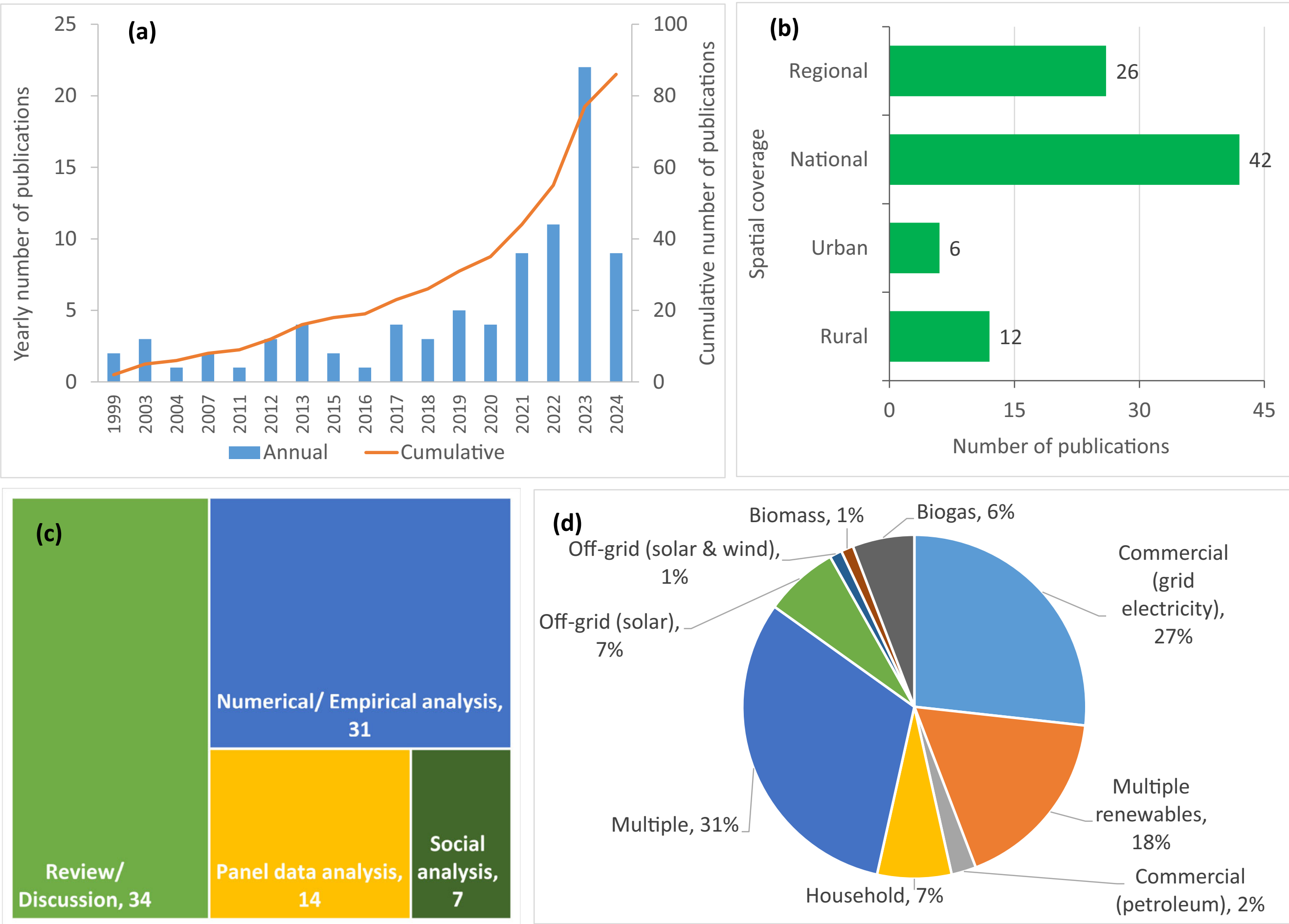

FIGURE 5 Summary of reviewed papers by: (a) number of publications; (b) spatial coverage; (c) type of study; and (d) fuel type ($n = 86$).

irrigation, and disaster response under the Renewable Energy Subsidy Policy 2016. Most importantly, Nepal was finally declared 'loadshedding free' in May 2018 (right edge of the dark gray block in Figure 3). Considering the esthetics of cities, underground cabling of its electricity distribution system in the urban areas is being currently carried out by NEA from 2020.[1] The Renewable Energy Subsidy Policy was updated in 2022 with focus on promoting loans instead of subsidies for the rural poor, reducing capital costs, increasing the renewable energy market, and strengthening local capacity. The Renewable Energy Subsidy Delivery Mechanism 2022 incorporated provisions for reverse auctions and other improvements for providing subsidies for improved off-grid renewable energy technologies in rural areas.

3.2 | Systematic literature review

Our keyword-based search and systematic review yielded a final cumulative list of 86 published papers from 1999 to March 2024 (Figure 5a), many of them have been published after 2020. Additionally, a majority of the articles consider the national energy context of Nepal ($n = 42$), followed by regional analysis ($n = 26$) (Figure 5b). Most of the articles were of review or discussion ($n = 34$) and numerical or empirical analysis ($n = 31$) type (Figure 5c). Similarly, a considerable number of the papers dealt with multiple types of energy sources (31%), studies on commercial grid electricity ranked second (27%) while those on biomass and off-grid solar-wind hybrid ranked last (1% each) (Figure 5d). Most of these studies focus on the applicability of a particular generation technology such as hydropower (Gyanwali et al., 2020; Hussain et al., 2019; Ogino et al., 2019; Singh et al., 2020); solar (Gautam et al., 2015; Kafle et al., 2023; Lin & Kaewkhunok, 2021); biogas (Kevser et al., 2022; Lohani et al., 2024; Rupf et al., 2015; Thapa et al., 2021) and micro- and mini-grids (Yadoo & Cruickshank, 2012). These figures indicate that research on the development and use of multiple types of energy sources and national level planning are slowly gaining attention in Nepal. Studies specifically focused on urban and rural areas and those making socio-technical assessments were limited. Moreover, publications holistically dealing with policy issues were scarce (Supplementary Material S1).

4 | DISCUSSION

4.1 | Availability

Three categories of energy sources, namely, traditional (firewood, agriculture residue and dry dung for direct combustion; 64.2%), commercial (petroleum, coal and grid electricity; 33.3%) and other renewables (2.5%) constituted the energy generation mix of the country in 2022/2023 (WECS/GoN, 2023). The country has made progress (after the enactment of Hydropower Policy 1992, 2001 and Water Resources Act 1992, 2002) in expanding the national electricity grid. Rural electrification through micro-hydro and off-grid solar PV systems, along with household and community level biogas, has been successful in remote areas. AEPC/GoN (2021) reports that the total installed capacity of rooftop solar PV is 10.1 MW, that of micro- and mini-hydropower is 38.8 MW and local hybrid grids is 2.7 MW. The current installed capacity of solar PV (including off-grid as well as local-grid connected systems) is estimated at 75.04 MW (MoF/GoN, 2023). Private sector involvement in electricity generation has also increased significantly. For example, the private sector (called "Independent Power Producers" in Nepal) generated 1,477 MW of hydropower during 2022/23 which accounts for 55% of the total power installed capacity of Nepal (NEA/GoN, 2023). Moreover, off-grid systems are generally successful in remote areas of the country because of the large government subsidies (Bhattarai, Maraseni, Apan, & Devkota, 2023). There has been a decrease in the share of traditional fuels by about 23% in 2022/2023 (64.2%) compared to 2008/2009 (87.1%) but at the cost of 18.2% increase in petroleum and coal (from 10.2% to 28.4%) (WECS/GoN, 2010; WECS/GoN, 2023). Grid electricity has increased from 2 to 4.9% and the share of other renewables has increased from 1.5% to 2.5% during this period (WECS/GoN, 2010; WECS/GoN, 2023). Moreover, household (mainly cooking by traditional fuels) is still the largest energy-consuming sector (~60%) of the country.

Despite changes in magnitude, alteration in the shares of the different clean energy generation technologies and uses is not impressive.[2] The Water Resources Strategy 2002 aimed at generating 820 MW of hydroelectricity domestically by 2007, 2,230 MW by 2017 and 22,000 MW by 2027, which seem very ambitious considering the past developments. Similarly, the National Water Plan 2005 aspired to generate 2,035 MW by 2017, 4,000 MW by 2027 and increase the per capita electricity consumption to 160 kWh by 2017 and 400 kWh by 2027. Nepal has not yet met these targets. The Whitepaper 2018 aimed to increase the per capita consumption of electricity to 700 kWh by 2023 and 1,500 kWh by 2028 by generating 5,000 MW of hydropower by 2023 (which was not achieved) and 15,000 MW by 2028, which looks unachievable under current development trends.

Interestingly, Nepal ranks as the top-most progressive nation in 2020 in terms of its energy equity with a 212% increase from 2000 (WEC, 2021). This has been largely attributed to its "exceptional" increase in urban and rural electrification schemes during this period. Although 94% of the population has access to electricity (WECS/GoN, 2023), the rate of access to 'quality' (as defined by IEA, 2021) grid electricity is about 70%. Almost the entire rural and remote areas are completely reliant on off-grid, low power, intermittent and temporary electricity generated from micro-hydropower, solar and hybrid plants which is barely enough for lighting or small uses like mobile phone charging.[3] Some community level off-grid projects are in operation but the hassle of the user groups and other financial and political issues generally make such projects ineffective over a period of time. Nevertheless, studies have shown that access to electricity leads to multiple benefits particularly for rural women (Shrestha, Jirakiattikul, & Shrestha, 2023). Even the urban areas connected by national grid do not get 'quality' electricity in the required amount throughout the day and year-round. As recent as until seven-eight years ago, NEA was able to provide electricity only for an average of less than 16 h a day to the capital city Kathmandu (NEA/GoN, 2014; NEA/GoN, 2019). As a result, the Nepalese are used to living in a condition of "loadshedding" (which is synonymously used to refer to blackouts in Nepal), meaning an intentional shutdown of power in some designated areas (often managed by weekly rotation) in order to avoid the central electricity system from collapsing when the demand exceeds its capacity. The country was 'loadshedding' free in 2018 with improved management of NEA as well as importing deficit power from India, mainly during the dry season (NEA/GoN, 2019). However, there are concerns among people that such power cuts might be back soon especially in the context of climate change and natural disasters which adversely impact hydropower generation.[4] Hence, such global metrics need to be carefully interpreted considering the ground zero realities of Nepal.

4.2 | Affordability

The domestic sector is largely dependent on traditional fuels (mainly fuelwood) sourced from private land and community forests at cheap rates (MECS/WINROCK, 2022). Fuelwood required for cooking is collected by the people irrespective of whether they get any external support because it is for one of the basic needs of life — food. In other words, the financial support from the government has always been extremely low in this regard.[5] That could be one of the reasons why the government has not been eager to initiate programs and be aggressively involved in replacing the traditional fuels with modern renewable ones. There is evidence in developing countries having to spend one-fifth of their income on wood for cooking, devoting one-quarter of domestic labour collecting fuelwood and ultimately suffering from life-ending pollution from inefficient combustion (Sovacool, 2012).

The transportation sector (with a share of 10.5% of the total energy consumption, WECS/GoN, 2023) relies heavily on fuel imports from India at consistently increasing prices (MoF/GoN, 2023). In the fiscal year 2019/20, Nepal imported fuel worth 1.8 billion USD, contributing to 16% of the total national trade deficit (MoF, 2021). The government regards income from the heavy taxes and duties levied on vehicle imports as a good source of income (DOC, 2020). However, it is creating a massive burden on the public. Likewise, Ghimire et al. (2023) and Shakya et al. (2024) showed that there is a varied perception in the adoption of electric vehicles in Nepal which needs to be leveraged by updating supportive measures. Rajbhandari et al. (2024) demonstrated a highly favorable scenario of energy security and GHGs reduction through electric mobility in the Kathmandu

Valley. Moreover, subsidies to off-grid rural energy systems are regularly revised, but there are doubts as to whether the subsidies are reaching those in need (Bhattarai et al., 2018).

Furthermore, entrepreneurs and industrialists generally maintain petrol/diesel generators energy backup systems and invertors because of lack of quality energy/electricity supply from the state. As a result, the production cost of goods become too high to compete with other cheaper options from India and China. This causes reluctance among the businessmen to invest in the productive sectors hindering economic development.[6] Nepal has a low per capita GDP of 1336.50 (current US$) and is highly susceptible to multidimensional poverty (Abbas et al., 2022; WB, 2024). Availability of sufficient energy for use in the productive sectors (such as manufacturing and commercial) generates economic output. If the country is better off economically, it travels up the energy ladder with increased use of modern energy technologies which further adds to improved living standards of the people, better employment opportunities and increased economic outputs. The government has been trying to establish a one-door policy for small organizations and community level businesses, but there is a lack of coherence among the concerned departments and different in-line agencies.[7] Studies indicate that households and businesses are willing to pay more for a reliable supply of grid electricity and clean energy technologies, reflecting a preference for clean energy over traditional fuels (Das et al., 2022; Niroomand & Jenkins, 2020).

The Nepal Oil Corporation (NOC), responsible for selling petroleum and LPG, consistently sells these fuels at higher prices in Nepal than the international market, but claims losses.[8] This results in unstable fuel prices and erodes trust of the general public on NOC due to opaque pricing methods. However, government policies lack transparency in pricing and cost predictability.[9] Furthermore, despite an increase in domestic hydropower generation, Nepal still has to import electricity from India (for example, 1543 GWh in 2021/22 @ US¢ 6.2/kWh), with very little export (493 GWh @ US¢ 4.3/kWh) at varying rates resulting in rising electricity prices (NEA, 2021). Natural disasters like the 2015 earthquake and the economic blockade imposed by India in 2016 have worsened the situation. The recent rejection of the power sector reform bill by the parliament, which aimed to remove monopolies in NEA and NOC, has added to the uncertainty in the fuel market.

4.3 | Technology

Renewable energy technologies and rural electrification have been consistently emphasized in Nepal from the early 2000s (Pokharel and Chandrashekar, 1998; Bastakoti, 2003; Pokharel, 2003), during the 2010s (Gurung et al., 2012; Nepal, 2012; Sovacool et al., 2011), and until recently (Lohani et al., 2023; Neupane et al., 2022; Zou et al., 2022). However, Nepal's energy generation mix is still dominated by traditional fuels (MoF/GoN, 2023). In rural areas, 51% of the population relies on firewood for cooking, 2.9% use dried dung while only 1.2% use bio-gas and less than 1% use kerosene or other sources (CBS, 2021). Studies have highlighted the importance of national income and extraction of available natural resources for energy accessibility and security in low-income economies (Aryal et al., 2023; Chiwaridzo, 2024; Xia et al., 2023). Hydropower is the main source of electricity, with small contributions from solar and thermal technologies; petroleum and LPG are used for transportation and urban cooking, respectively. Majority of the population lives in cities, where grid electricity is available, but access and availability are challenging in rural areas.[10] Off-grid small-scale renewable energy technologies such as micro-hydro, solar, wind, hybrid technologies and biogas are relatively cheaper. Technologies such as 'Solar Tuki', could be considered a revolution nearly two decades ago (Chitrakar & Shrestha, 2010), but not anymore. Such small off-grid energy systems are not sustainable in the long run as modern electronic appliances require more energy than that provided by small panels and LEDs[11] as people move up the energy ladder (Bharadwaj et al., 2023; Dominguez et al., 2021). However, as Afridi et al. (2023) mentions, renewable energy development in South Asia is dominated by photovoltaic and wind technology but the utilization of available bioresources is generally overlooked. Additionally, Chen, Xu, et al. (2023c) argued that Nepal needs to prioritize improving the operational performance of large biogas plants. Studies such as Parajuli et al. (2023) also show the effectiveness of thermal energy storage devices for energy savings in Nepal while Bhandari and Subedi (2023) see prospect in hydrogen production in the future. Complementary technologies such as wind-solar PV-hydropower have been tested in Latin America with promising results (Gonzalez-Salazar & Poganietz, 2021). Moreover, micro-hydro based mini-grid technologies have been recommended for developing countries (Mainali & Silveira, 2013; Sanjel & Baral, 2021; Yadoo & Cruickshank, 2012). In addition, with Nepal's focus on development of large hydropower projects, grid extension to mountainous and hilly areas has gained momentum after the mid-1990s.[12] Subedi et al. (2023) not only highlights the benefits of decentralized energy systems through micro-hydropower in Nepal, but also depicts the variations in the benefits due to varying topography and socio-economic conditions.

Unfortunately, Nepal lacks domestic capacity to adapt to changing energy environment.[13] Moreover, concerns over the impacts of natural resource availability and extraction and its ecological impacts have been raised by studies such as Sun and Gao (2023). The government owned research institution – Nepal Academy of Science and Technology (NAST) has a poor outreach and academic credibility which it outcasted by bureaucratic and political aggravations.[14] Research carried out in academic institutions are neither action oriented nor applicable in strengthening local indigenous technologies.[15] International support is needed for policy preparation (Table A2). Notwithstanding, the recently commissioned Upper Tamakoshi Hydropower Project (456 MW) and currently under construction projects, such has Tanahu (140 MW), Rasuwagadi (111 MW), Middle Bhotekoshi (102 MW), among others are indicative of a generous electricity supply in the near future (NEA, 2021). The provisions of tax subsidies for energy-efficient manufacturing equipment (for example envisioned by the Industrial Policy 2011 and Industrial Enterprise Act 2020) have not been realized adequately because of administrative and bureaucratic hurdles.[16] Furthermore, the construction of a two-million metric tonnes per year capacity trans-border petroleum pipeline between Motihari (India) and Amlekhgunj (Nepal)[17] raises concerns about India's increasing influence on Nepal's economy through fossil fuel exports,[18] and Nepal's lack of concrete plans to replace fossil fuel usage with domestic energy.[19]

4.4 | Sustainability

Model-based simulations such as WECS (2013), Mali et al. (2022), Dhakal et al. (2021) and Shakya et al. (2023) have explored feasible future energy mix options for Nepal. The current import-as-needed model in Nepal's transportation sector and electricity supply is unsustainable.[20] However, recent studies indicate erratic monsoons, posing risks to Nepal's water and energy supply (Bhattarai, Bhattarai, et al., 2022, Bhattarai, Devkota, et al., 2022, Bhattarai, Devkota, Maraseni, et al., 2023; Marahatta et al., 2022; Chinnasamy et al., 2015). Storage type hydropower projects could buffer these impacts, but adhering to robust environmental considerations are crucial.[21] Despite campaigns to decommission dams in some countries (Moran et al., 2018), Nepal needs storage projects to manage issues related to "too-much" and "too-little" water and energy security issues emphasized in key documents like the 1985 Master Plan of Koshi Basin, 2014 Nationwide Master Plan of Storage Hydropower Development in Nepal by JICA, and WECS (2013). Studies at the global level on small hydropower development show prospects of continuation of this technology if planned carefully (Ptak et al., 2022).

Diversification of the energy generation mix has been the current focus of Nepal's energy policies. Studies have reported a common problem of developing countries such as Nepal in formulating policies only when a development intervention is necessary without pre-planning comprehensive sectoral policies (Luthra et al., 2015). Sustainable Development Goals—Status and Roadmap 2016 focused on the generation of electricity through large hydropower projects for national grid and off-grid micro-hydro and grid connected solar system, prioritizing budget for operation and maintenance for the system for a steady quality of electricity. The Fifteenth Plan (2019–2024) targets a 12% contribution of renewable energy in total energy consumption. The National Environment Policy 2019 envisions reduction of household pollution by renewable energy technologies. The Second Nationally Determined Contribution aims for a 15% contribution of renewables in the energy mix by 2030, including hydropower, electric stoves, solar systems, electric vehicles, and private plantations. The Long-term Strategy for Net Zero Emission 2021 emphasizes conversion of LPG use to electricity and biogas, and reduction of emissions within Nepal and beyond through power trade of hydro- and solar-electricity.

Cross border electricity trade takes place currently between India-Bhutan, India-Nepal and India-Bangladesh which have been made possible by bilateral government-to-government (G2G) arrangements based on case-to-case negotiations (SARI/EI, 2021). Dating back to the 1920s, India-Nepal transborder electricity cooperation has evolved over time with currently 20 interconnection corridors (one at 400 kV capacity; four at 132 kV capacity; and others at 33 and 11 kV capacities) for electricity exchange and trade (SARI/EI, 2021; Sharma & Awal, 2013). India's own hydroelectricity potential is estimated at about 145 GW while the electricity demand of Nepal is about 0.5% of India. Unless the domestic demand for electricity in the industrial, commercial and transportation sectors increases significantly, Nepal will have surplus electricity in the near future which will most likely be wasted if not exported at lucrative rates to the neighbor energy hungry India (USAID-SARI, 2003). In the FY 2022/2023, Nepal purchased 1,855 GWh year-round from India and exported 1,333 GWh (∼72% of imported electricity) during June to October but at disproportionate prices (NEA/GoN, 2023). The governments of Nepal and India have recently signed energy sharing agreements in which India has agreed to buy electricity only from the hydropower projects to be built in Nepal with Indian funding/construction contract (for example, 679 MW Arun-4, 900 MW Arun-3, 750 MW West Seti, 900 MW Upper Karnali, 450 MW Seti River-6, 480 Phukot Karnali and 1,902 MW Mugu Karnali, amounting to a total of about 7,000 MW) which is a biased agreement (Qazi, 2022). India gains the larger benefits while Nepal has to deal with the environmental and social implications throughout its project life at the price of a small amount of electricity for domestic consumption. India-Bhutan (SARI/EI, 2017; SARI/EI-IRADe, 2018) and Thailand-Laos models (ADB, 2009; Hecht et al., 2019; Suhardiman et al., 2014) of cross border trades could be beneficial for both parties in which the economically better country invests in the projects and also reaps most of the benefits while the poorer country is also benefitted. Nevertheless, the bilateral agreements of cross-border trade including building and upgrading of the power lines can be considered a milestone for ensuring a foreign market for Nepal's electricity (Shrestha, 2023).

Nepal and China have recently made formal agreements in 2017 to carry out joint feasibility studies of natural gas and petroleum and also establish hydropower projects and transmission lines in Nepal (ET, 2017) boosting its technological and economic development. There have been recent efforts from Nepal and Bangladesh for cross-border electricity trading provided India gives access to the infrastructure for which it had shown reluctancy in the past (Chaudhary, 2023; Shrestha, 2023). Moreover, Nepal's Energy Sector Vision 2050 has identified hydro-power as the "lead" energy sector for meeting the long- and short-term energy demands of the country (WECS/GoN, 2013). Similarly, ADB has also recognized Nepal's efforts in improving energy security and leaping towards economic growth by accelerated sustainable development of hydropower (ADB, 2017). Economic value addition to the products utilizing cheap electricity could fetch high profit margins in the regional market. WEC (2021) very rightly stated that success of net zero targets, committed by many nations in their future energy plans, is primarily governed by the people and practicalities rather than the often-exaggerated political promises and plans. Moreover, sincere political commitment, large investment in technology and infrastructure, institutional capacity building and harmonization of standards and regulations are the key requirements for successful cross-border energy trade models (SARI/EI, 2021).

Therefore, the prospects of surplus electricity export from Nepal, and petroleum products and electricity import from India during the respective high demand times could play a key role in maintaining regional energy balance in South Asia. However, Gyanwali et al. (2023) warns of the possible reduction in hydropower generation and cross-border electricity export as a result of climate change in the future and also recommends diversified generation mix. Sharma and Shrestha (2023) have explored additional energy generation pathways that Nepal needs to adopt to reduce its reliance on petroleum in the short- and long-runs. Additionally, Pokharel and Regmi (2024) have recommended the need for location-specific strategic planning for hydropower projects in Nepal. Although India had nominated the Power Trading Corporation as the focal agency for dealing with matters related to power trade with its counterpart NEA of Nepal in 2001 (ADB, 2007), Nepal has not been able to reap benefits as expected from this collaboration.

Budget availability is a critical factor for the sustainability of development projects in developing countries (Mohsin et al., 2021; Müller et al., 2021). Middle-income countries such as Thailand also have been reported to have concerns over the high capital cost of renewable energy technologies in comparison to conventional energy resources (Adhikari et al., 2008). National funds such as the REF (in the Ninth Plan 1997–2002) and CREF (in the Three-year Interim Plan 2010–2013) have been created and mobilized for rural renewable energy. International support has been provided to Nepal by organizations like SNV and GTZ for off-grid solar and biogas systems (Cheng et al., 2014). Norway has been an important donor for hydropower development in Nepal. However, it has been seen across many developing regions that subsidies and donations are not effective in establishing renewable energy technologies, particularly in the rural areas (Bhattarai, Maraseni, Apan, & Devkota, 2023; Pandey & Sharma, 2021; Windemer, 2023). Instead, soft loans and credit mechanisms through local cooperatives and financial institutions are believed to be more effective (Wagemans et al., 2019; Mainali and Silveira, 2013). Although credits were envisioned from as early as the Eighth Plan (1992–1997), subsidies have dominated the renewable energy sector until recently, impacting its financial sustainability. Sovacool et al. (2013) recommended increasing electricity tariffs. However, this does not seem to be preferred as a large share of the current Nepalese population is already unable to afford electricity at the existing price. Developing an "energy ecosystem" for sustainability has been recommended (Bhattarai, Maraseni, Apan, & Devkota, 2023). Recent revisions of the rural energy policies are indicators of this desired change which needs to be further strengthened.[22]

4.5 | Governance

Good governance needs prime attention in the Global South (Baniya et al., 2021; Haifa et al., 2023). People have their expectations on the availability and use of energy while the government has its limitations. Nepal's energy sector has been impacted by political turmoil, unstable government, and changing national plans, unable to meet the energy expectations. Rural energy policies focus on off-grid isolated renewable energy, while electricity acts push for grid expansion even to the remote areas. However, there are unanswered questions about long-term management of off-grid renewable energy technologies, disposal of energy waste (for example, dead batteries which have been problematic in the past (Alex et al., 2014)), conversion technologies of DC to AC appliances, cost of conversion, the future role of community energy user groups and the exit strategy for organizations such as AEPC that have worked in the rural energy sector for a long time. Connecting to the national electricity grid is still considered a status symbol in rural Nepal.[23] While theft control and transmission losses have decreased (from 25% in 2013 to around 13.5% in 2023 (NEA/GoN, 2023)), with positive roles of policies such as the Electricity Theft Control Act 2002, poverty remains a main driver of theft[24] as with rural people of many developing countries (Luthra et al., 2015). Similarly, corruption and preferential treatment are common in Nepal which is a direct result of weak governance and condition of lawlessness (Sovacool et al., 2011; Sovacool & Bulan, 2012). These problems lead to favouring projects and polices which have vested interests of national and international drivers.[25] Furthermore, Naz & Aslam (2023) highlight the important role of governance in South Asia to moderate the environmental impacts of globalization, financial development through innovative approaches.

The Government of Nepal has established separate institutions to manage the power sector instead of sole reliance on NEA as 'institutional de-bundling' efforts. The Hydroelectricity Investment and Development Company Limited was established in 2011 for management of investment in middle to mega hydropower projects in Nepal.[26] The Rastriya Prasaran Grid Company Limited, established in 2015, is responsible for transmission and evacuation of power for the hydropower sector. It has been successful in preparing a consolidated transmission development plan for Nepal.[27] Similarly, the Vidhyut Utpadan Company Limited was established in 2016 to develop large hydropower projects in the country adopting different development modalities such as public private partnership (PPP) and build-own-operate-transfer (BOOT).[28] Similarly, the Electricity Regulatory Commission was established in 2018 for technical management, electricity tariff fixing, regulation of power purchase rate, address consumer welfare aspects and advising the government on related issues. However, politicization and lack of expertise and resources have hindered the proper functioning of these institutions.

Local authorities have been given more power regarding the use of local resources, including energy generation, for example through the implementation of the Local Self-Governance Act 1999, as well as the Environment-friendly Local Governance Framework 2013 and 2021. However, their capacity for such a transition is questionable.[29] There are concerns that subsidies for renewable energy may actually increase the rich-poor disparity rather than reducing it (Nepal & Paija, 2019; Paudel, 2021). The marginalized and disadvantaged groups are still the largest sufferers in terms of energy access and use

(Lin & Kaewkhunok, 2021; Paudel, 2021; Rahut et al., 2022; Shrestha, Jirakiattikul, Lohani, & Shrestha, 2023). Hydropower projects planned in the 1990s (for instance, the Arun III Hydropower Project (900 MW), Upper Karnali Hydropower Project (900 MW) and Budhi-gandaki Hydropower Project (1,200 MW)) have been disrupted for decades due to political reasons, local interferences and conflicting national-international interests. There are discrepancies and overlaps in the roles of different organizations of the government in energy development. Moreover, Sovacool et al. (2011) doubts whether Nepal will be able to harness its enormous renewable energy (mostly hydropower) potential without developing an enabling environment through social awareness, community ownership, minimizing corruption and institutional and regulatory reforms. These issues warrant immediate serious consideration.

4.6 | Challenges and future direction

A study by Sovacool et al. (2013) identified six challenges and eight solutions for electricity development while Ghimire and Kim (2018) pointed out six barriers to renewable energy development in Nepal. Moreover, another study (Sovacool et al., 2011) cited political unrest and the economy as barriers to Nepal's hydropower development. Interestingly (from a researcher's perspective) and unfortunately (from the nation's development perspective), most of these issues remain valid today. However, the current policy-practice interface of Nepal faces significant challenges. As Rissman et al. (2020) rightly explains, no single policy is a "silver bullet". Extending this notion, we identify concerns, especially after the federal restructuring, and suggest future directions for sustainable development of Nepal's energy sector.

4.6.1 | Political fragility and weak governance

The impacts of political instability can trickle down across the entire development hierarchical system of a country (Bhattacharya & Jana, 2009). Political instability has had a negative impact on Nepal's energy sector and economy, resulting in insufficient energy generation, inefficient energy use, high dependence on imports, and reliance on international support. Power sector reform can be directly linked to political stability in South Asia (Bhattacharyya, 2007). India was able to adopt a broad energy framework in 2003 which was reinforced in 2008 (Ahlers et al., 2015), however other countries were significantly delayed. Nepal's economy declined considerably after the transition to a democratic system in the early 1990s, with derailed policies and shutdown of government-owned industries in the name of privatization.[30] In addition, the Maoist insurgency devastated the industrial and commercial sectors, causing several energy development (particularly large hydropower) projects to be either significantly delayed or canceled (Sovacool et al., 2013). Policies have been supportive of a positive change (Supplementary Material S3). Moreover, Borozan (2022) argues that even in the G7 countries, a well-developed, stable and transparent economic, energy and environmental policy framework is necessary for attaining energy stability. However, Nepal's past experiences have not proven to be investment-friendly especially in the renewable energy sector,[31] which may retard foreign investment in the foreseeable future.

Nepal's administrative and restructuring activities since becoming a federal state in 2015 have further delayed policy making and caused instabilities.[32] The GoN has taken a crisis-management approach to energy-related problems, for instance, by formulating the Nepal Electricity Crisis Resolution Action Plan 2008. Rural areas are still dependent on conventional fuels for cooking and the transportation sector completely relies on petroleum imports (Bhattarai, Maraseni, Devkota, & Apan, 2023). The urban domestic areas are temporarily provided with 'loadshedding-free' grid electricity while the industrial, manufacturing, and commercial sectors are still minor energy consumers.[33] The Environment-friendly Local Governance Framework 2013 and 2021 have promoted resources utilization at the local level but their operationalization differs significantly because of the difference in hierarchical structure of the government.[34] Moreover, the policies enacted around 2015 (Table A1 and A2) were either automatically repealed or later revised due to national restructuring, limiting the assessment of their effectiveness.

Political instability, social acceptance issues, and lack of energy transition management capabilities have contributed to sluggish power sector development in South Asia (Bhattacharyya, 2007), including Nepal. Besides, in the absence of employment possibilities in the productive industrial and commercial sectors, 23.3% of the households have at least a family member living abroad (out of which 82.2% are males) seeking for better work opportunities CBS (2021). Additionally, excessive reliance on India for construction of large hydropower projects in Nepal (such as the 762 MW Tamor, 679 Lower Arun and 900 MW Arun-3, among others) amounting to over 8,000 MW raises questions about India's unnecessary intervention in Nepal's water resources and power sector.[35] The Upper Karnali Hydropower Project which was identified in the early 1990s was occupied by an Indian company (GMR) for almost three decades,[36] the development of which is extremely slow.

To improve Nepal's energy sector, domestic energy needs should be prioritized by setting short- and long-term policies accordingly. Transparency and responsibility are needed from political parties and leaders to reduce instability and attract private investments from within the country and abroad. Construction of storage-type hydropower projects at strategic locations and strengthening transmission and distribution systems are essential to ensure adequate electricity supply. Increased employment opportunities in industrial and commercial sectors will help alleviate poverty (Thapa-Parajuli et al., 2021) and play a significant role in reduction of corruption and electricity theft. Making policy instruments rigid and improving the variable electricity tariff system will lead to good governance and energy security (as in China (Chen, Xu, et al., 2023)) and avoid repercussions (for instance warned by Wolde-Rufael (2009) in Africa). Additionally, the applicability of modern measures such as net-metering and real-time pricing of electricity also needs careful consideration.

4.6.2 | In-silo operation modality

Recognizing its multi-disciplinary outreach, use of energy in various sectors of the economy is crucial for the prosperity of a country (Huda & McDonald, 2016; Ogino et al., 2019; Rijal, 1999). However, Nepal's approach to energy planning is siloed, with different ministries and agencies working independently, leading to inefficiencies and missed opportunities (Ghimire & Kim, 2018; Lohani et al., 2023). Reasons of administrative hassles, political interferences and corruption can be held responsible.[37] The Electricity Act and Hydropower Development Policy mainly focus on hydropower, while others such as the Rural Energy Policy and Renewable Energy Subsidy Policy target alternative energy technologies for rural areas. Cross-sectoral collaboration among ministries (for example, Ministry of Forests and Environment, Ministry of Education, Science and Technology, Ministry of Physical Infrastructure and Transport, Ministry of Industry, Commerce and Supplies and Ministry of Agriculture and Livestock Department, among others) and other line agencies is necessary for the country's development (Sovacool et al., 2013), with a larger goal of national development rather than focusing on individual interests. The development of the Hydropower Environmental Impact Assessment Manual 2018 is a positive step towards cross-sectoral collaboration. Flexibility in policies and dedication and perseverance among participating agencies are needed. Moreover, a bureaucracy-technocracy-society-synergy is felt necessary.

4.6.3 | Lagging research and development

Research and development (R&D) in Nepal's energy sector is limited. Several dedicated departments and units exist within the government, but they face limitations due to inadequate resources. For instance, the Water and Energy Commission Secretariat (WECS) is the apex institution in providing research and policy feedback on water and energy issues, but its role in energy planning is constrained by limited human resources and institutional capacity. The Ministry of Energy, Water Resources and Irrigation (MoEWRI) has an Electricity and Energy Policy Unit; the Nepal Electricity Authority has a Planning, Monitoring and Information Technology Directorate; and the Water Resources Research and Development Centre under the MoEWRI has the mandate for training, handling laboratories and research facilities. Data collection is centralized in Nepal and access is limited. For example, the Department of Hydrology and Meteorology (DHM) collects hydrological and climatic data through its network of observation stations in the country. However, access to their data is constrained by a lengthy administrative process[38] leading to reliance on global datasets and potential failures in energy generation projects. The Policy Research Institute (PRI)[39] formed in 2018 lacks research professionals and partnerships with academic institutions, limiting its impact. Action research as well as policy research need to be collocated (Creutzig et al., 2014). Investment in R&D is needed to incentivize private/public institutions and integrate awareness of energy-saving among the public for socio-economic development (Tang et al., 2016). Moreover, studies have recommended increasing investments in education, human capital and R&D for sustainable development (Chen & Guo, 2023). With burgeoning issues of climate change, the country has made efforts to promote commercial solar, wind and hybrid projects (Tiwari, 2021). Furthermore, Pandey et al. (2023) demonstrate how climate induced reduction in water availability and mechanical failures of hydropower projects due to lack of regular maintenance are taking a toll on Nepal's electricity sector. Other countries of the global south, for example Brazil, is the ninth-largest electrical sector in the world with a generation mix consisting of 64% hydropower, 26% thermal, 9% wind and 1% solar power plants (Ávila et al., 2021). Recent studies in Nepal have recommended advanced technologies such as pumped storage hydropower (on- and off-rivers) and peaking ROR projects (Baniya et al., 2023; Lohani & Blakers, 2021). The hybridization of technologies to obtain co-benefits such as solar panels over irrigation canals (Kapoor, 2021), agrivoltaics (Barron-Gafford et al., 2019) and floatavoltaics (Almelda et al., 2022), which have been successfully piloted in many developing regions, could be beneficial with customization to local conditions. Recent studies such as Shrestha et al. (2024) show the possibilities of latest methods such as deep learning to optimize power systems for stability and sustainability especially for integrating renewable energy sources into mainstream national power generation system. The government needs to mainstream R&D and allocate sufficient funds, while education policies should encourage energy development in technical curricula.[40]

4.6.4 | Demand side management

Nepal has focused on supply-side management of energy over the past four decades. Despite policies such as the National Energy Efficiency Strategy 2018 and the Industrial Enterprise Act 2020, the provisions have not been effectively put into practice due to lack of public awareness, limited investment in modern appliances, and ineffective promotion of efficient devices by the government.[41] As a result, the domestic sector is still highly reliant on inefficient traditional fuels (CBS, 2021). Energy consumption needs to be controlled efficiently (Butchers et al., 2020; Fares & Webber, 2017). Moreover, Chen, Xu, et al. (2023) concludes that national efforts of controlling energy consumption by ‘regulation priority’ and ‘technology-driven and industrial structure upgrading’ have played a key role in China's decarbonization. In the context of Nepal, strengthening local cooperatives and financial institutions and motivating them to invest and promote energy-efficient devices is important. Energy efficiency in the industrial and transportation sectors also need to be promoted. Developing the R&D capabilities of the country to innovate and design efficient technologies is essential for long-term energy security. Paudel et al. (2023) explain how reducing monthly energy expenses and providing uninterrupted supply of electricity is beneficial for sustainable energy transition in Nepal. However, the social acceptance of newer technologies should not be assumed, in the developing world (van der Gaast et al., 2009) and developed world (Windemer, 2023) alike.

Moreover, new renewable energy technologies might not always be efficient, environmentally friendly, cheap and just, as they are usually claimed (Bhattarai, Bhattarai, et al., 2022; Bhattarai, Devkota, et al., 2022; Bhattarai, Maraseni, & Apan, 2022; Pietrosemoli & Rodríguez-Monroy, 2019; Sovacool & Dworkin, 2015). Cloke et al. (2017) argues that three forms of literacy — 'energy systems literacy', 'project community literacy' and 'political literacy' — are required to materialize energy projects. Policies need to address this niche.

4.6.5 | Continued dependence on international support

International donors and technology transfers have played a significant role in Nepal's renewable energy development (Bhandari et al., 2017; Gautam et al., 2015; Pokharel, 2003). Development agencies and international banks had important stakes in hydropower development in the 20th century while local private financial sectors are more involved in recent times (Ahlers et al., 2015). For instance, long-term aids in the energy (particularly hydropower) sector provided by Norway dates back to the 1960s and the aid dependency increased from 34% of the national budget in the mid-1970s to 70% in the mid-1990s (Movik & Allouche, 2020). However, over-reliance on subsidies and lack of collaboration between donors, government, local enterprises, and communities (Alex et al., 2014; Bhattarai et al., 2018; Dhital et al., 2016) have hindered sustainable progress. Nepal's energy assessments and planning still heavily depend on international support (Table A1 and A2), indicating a lack of prioritization of local capacity building. To address this, a "proper energy ecosystem" that focuses on local technical capacity enhancement, strengthening of local enterprises, community empowerment, and building a productive energy market is necessary. This requires a bottom-up approach with active collaboration of beneficiaries (Schulz & Saklani, 2021; Singh et al., 2020) from policy formulation to implementation phases. Vij et al. (2023) have demonstrated an interesting interplay of power at the local to transboundary levels while designing and implementing climate change policies in South Asia. Moreover, the international development partners and donor agencies also need to target their programs in an unbiased, fair and inclusive manner.

We acknowledge some limitations in this study. The main focus of our study was on the qualitative analysis of policy progression. A quantitative assessment of the cross-border trade from Nepal was beyond the scope of this review. In addition, an economic evaluation of the policy impacts on multiple sectors of the economy could be an excellent continuation of this research.

5 | CONCLUSION AND POLICY IMPLICATIONS

Using a mixed-method approach, this study tracked Nepal's energy policy progression from 1984 to 2022 applying a global energy security framework encompassing five broad dimensions (availability, affordability, technology development, sustainability and governance). Our findings reveal a progressive trend in Nepal's energy policies. Moreover, attempts to diversify the energy generation mix and increase energy use efficiency across the rural and urban domestic areas are positive indications. While the government's actions to meet the energy demands of remote rural areas using off-grid small renewable energy technologies are praiseworthy, there are several challenges and opportunities that need to be addressed.

The key take-away messages from our analysis are as follows:

5.1 | Progressive energy policies

Efforts from the Governement of Nepal as well as the private sector supported by policy updates have led to a considerable increase in the energy availability for Nepal. Overall access to electricity has significantly increased from 29% in 2000 to 92% of the population in 2021.

5.2 | Unaffordable energy

Despite the commendable efforts in the past, firewood still remains the primary energy source, especially in rural areas, with reliance of 51% of the population for cooking. Moreover, weak economic conditions, unstable fuel prices, and lack of trust in government agencies make clean energy unaffordable for most Nepalese.

5.3 | Renewable energy potential

Current fossil-fuel based technologies are not sustainable and will increase trade deficits and have long-term environmental implications. Limited renewable energy technologies such as hydropower, solar, and bio-gas are feasible in Nepal. However, the country lacks the technical and financial capacity to adapt to changing energy conditions. Moreover, there are high chances that subsidies for renewable energy may exacerbate the rich-poor divide.

5.4 | Barriers to sustainability

The absence of an "energy ecosystem" considering diverse spheres of the society has been a significant barrier for sustainability. Political turmoil, unstable government, changing national plans, lack of awareness in society, lawlessness, and corruption have hindered the energy sector's progress. Moreover, stakeholders' roles during policy formulation and implementation are often opaque and duplicated.

Based on our review, we provide the following specific policy recommendations:

1. *Supply-side management*: The state must accelerate its initiatives to harness the country's massive hydropower potential through strategic implementation of large storage projects to manage issues of

"too-much" and "too-little" water and energy, while meeting environmental requirements. Benefit sharing between load centres and across provinces, upstream-downstream benefits quantification (particularly for regulated flows in storage type hydropower projects) need careful attention at the policy level. Extension of the national grid to remote areas is necessary in the long run for maintaining energy equity among the urban and rural people. The current energy generation mix of Nepal needs to be diversified: prospects of solar, biogas and other hybrid systems need to be researched and implemented in feasible areas for achieving energy security. New interventions such as pumped storage, hybrid micro grids, net-metering of household solar PV systems into the central grids and real time energy pricing need to be mainstreamed. The federal and local governments should be given authority for resource accounting and planning to optimize the supply of energy locally.

2. *Demand side management*: It is the combined duty of the government as well as the users to utilize the available energy optimally. The government should aggressively raise awareness among the users, mainly the rural poor who are still largely dependent on conventional fuels for their domestic uses. Policies should collaboratively target replacing traditional fuels (primarily firewood) with cleaner alternatives such as electricity and biogas and promote the use of energy efficient appliances. The current trend of switching to LPG is not a sustainable solution. Tax reduction and subsidies for RE penetration are not sustainable, hence, subsidy policies need appropriate revision. Local cooperatives need to be strengthened for providing credits and loans. Moreover, increasing energy efficiency in the industrial, commercial and transportation sectors need to be promoted.
3. *Multi-sector collaboration*: Energy has impacts on various sectors of the economy. Involvement of different stakeholders using a bottom-up approach in the energy policy formulation process is a must. The science-policy interface needs to be strengthened with active collaboration of the concerned ministries/departments, private organizations, financial institutions, academia, community, and international partners. Implementing newer energy technologies by customizing them to the local conditions of Nepal through action-research and making policy recommendations for their establishment and sustainability is today's need. Therefore, roles of academic institutions, research organizations and think tank organizations in this regard should be clearly defined and should be sufficiently resourced through relevant policy reforms. Moreover, a proper "ecosystem" is necessary for proper functioning of the hardware and software of the energy sector. A bureaucracy-technocracy-society-synergy is strongly felt necessary.
4. *Political stability and good governance*: Development and economic prosperity is possible only by attaining a state of political stability, supplemented by supportive policies. The current practice of juggling national plans with frequently changing governments in Nepal needs to be ended. Formulation and intact implementation of a national level energy development plan is necessary irrespective of the change in government. Moreover, policies need to be strict in terms of good governance and regulation so that issues such as corruption, obstruction to energy development projects due to local and political interferences are discouraged. One door policy for the development of energy projects needs to be emphasized. Additionally, Nepal needs to focus on improving its diplomatic relations with the neighboring countries through revision in the foreign policies and foreign aid policies, enabling conducive environment for obtaining technical and financial support as well as exploring energy trade opportunities.

There is a possibility for Nepal to contribute to the ever-growing energy demand of South Asia, particularly of India and China. India is the nearest and the largest electricity market for Nepal. Electricity trades with Bangladesh and China are economically challenging and technically difficult mainly due to reasons of proximity and rugged terrain. The same can be observed for cross-border trade with other SAARC countries. Furthermore, setting up and adhering to a common set of operating rules and tariff fixation are challenging aspects that need to be focused on by the countries collaborating on energy sharing. Nepal should maintain diplomatic relations with its neighbors in which benefits are proportionate and just. In addition, an economic evaluation of the policy impacts on multiple sectors of the economy as well as a quantitative assessment of the cross-border trade from Nepal could be plausible avenues for future research.

Thus, incorporating these critical issues considering their multiple facets in the policy making process is imperative for achieving energy security, economic prosperity and sustainable development of Nepal. Formulation of proper policies in Nepal can be beneficial to South Asia through regional power trade and seasonal energy balance. Lessons learnt from this policy synthesis of Nepal could be insightful for other countries of the Global South sharing similar socio-economic and geo-political attributes.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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ENDNOTES

[1] https://myrepublica.nagariknetwork.com/news/nea-s-plan-to-lay-underground-electricity-cables-on-main-roads-of-kathmandu-valley-becomes-challenging/.

[2] Response from Expert#1 (government) [Please see Supplementary Material S3 for details of experts].

[3] Response from Expert#9 (international research organization).

[4] Response from Expert#10 (national research organization) and Expert#11 (private sector).

[5] Response from Expert#4 (academician) and Expert#10 (national research organization).

[6] Response from Expert#11 (private sector).

[7] Response from Expert#3 (academician) and Expert#7 (government).

[8] Response from Expert#11 (private sector).

[9] Response from Expert#2 (academician).

[10] Response from Expert#5 (government).

[11] Response from Expert#9 (international research organization).

[12] Response from Expert#10 (national research organization).

[13] Response from Expert#1 (academician).

[14] Response from Expert#9 (international research organization).

[15] Response from Expert#8 (government), Expert#9 (international research organization) and Expert#11 (private sector).

[16] Response from Expert#2 (academician) and Expert#11 (private sector).

[17] https://pib.gov.in/PressReleseDetail.aspx?PRID=1584627 (accessed June 10, 2022).

[18] Response from Expert#9 (national research organization).

[19] Response from Expert#6 (government) and Expert#7 (government).

[20] Response from Expert#3 (academician).

[21] Response from Expert#7 (government).

[22] Response from Expert#9 (international research organization) and Expert#10 (national research organization).

[23] Response from Expert#10 (national research organization).

[24] Response from Expert#8 (government).

[25] Response from Expert#11 (private sector).

[26] https://www.hidcl.org.np/.

[27] https://www.rpgcl.com/.

[28] https://www.vucl.org/.

[29] Response from Expert#10 (national research organization).

[30] Response from Expert#3 (academician) and Expert#10 (national research organization).

[31] Response from Expert#10 (national research organization).

[32] Response from Expert#5 (government), Expert#8 (government) and Expert#10 (national research organization).

[33] Response from Expert#10 (national research organization) and Expert#11 (private sector).

[34] Response from Expert#6 (government).

[35] Response from Expert#8 (government) and Expert#9 (international research organization).

[36] Response from Expert#2 (academician) and Expert#10 (national research organization).

[37] Response from Expert#1 (academician), Expert#6 (government) and Expert#9 (international research organization).

[38] Response from Expert#9 (international research organization), Expert#10 (national research organization) and Expert#11 (private sector).

[39] https://pri.gov.np/ (accessed January 18, 2022).

[40] Response from Expert#1 (academician) and Expert#4 (academician).

[41] Response from Expert#2 (academician), Expert#3 (academician) and Expert#10 (national research organization).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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APPENDIX A

TABLE A1 List of policies directly related to the energy sector of Nepal from 1979 to 2022 and their coverage.

			Sectors						Technologies												
			Domestic		Transportation				Hydropower		Solar				Biogas						
S. N	Policies	Year	Urban	Rural	Passenger	Freight	Industrial & Commercial	Others	Large & medium (grid electricity)	Small & micro	Off-grid	Grid connected	Wind	Hybrid	Household	Community	Others	Demand side management & efficiency	Legal/ institutional arrangements	Promotion of private/ international sector collaboration	Focus on Research and Development	Involved organizations
1	Gandaki River Basin Power Study	1979							✓													HMG, UNDP, SMEC, EPA, NED
2	National Electricity Act	1984							✓										✓			HMG
3	Master Plan Study on The Kosi River Water Resources Development	1985							✓													HMG, JICA
4	Water Resources Act	1992							✓										✓			HMG
5	Electricity Act	1992							✓													HMG
6	Hydropower Development Policy	1992	✓	✓	✓	✓	✓	✓	✓											✓		HMG
7	Electricity Rules	1993	✓						✓										✓			HMG
8	Hydropower Development Policy	2001							✓	✓								✓		✓		HMG
9	National Transport Policy	2001			✓	✓			✓			✓										MoPPW/ HMG
10	Water Resources Strategy	2002	✓	✓	✓	✓	✓		✓													WECS/HMG
11	Electricity Theft Control Act	2002	✓	✓					✓										✓			HMG
12	Nepal Electricity Authority Community Electricity Distribution Bye-Laws	2003		✓					✓											✓		NEA

(Continues)

TABLE A1 (Continued)

			Sectors						Technologies													
			Domestic		Transportation				Hydropower		Solar				Biogas							
S. N	Policies	Year	Urban	Rural	Passenger	Freight	Industrial & Commercial	Others	Large & medium (grid electricity)	Small & micro	Off-grid	Grid connected	Wind	Hybrid	Household	Community	Others	Demand side management & efficiency	Legal/ institutional arrangements	Promotion of private/ international sector collaboration	Focus on Research and Development	Involved organizations
13	National Water Plan	2005	✓	✓					✓													CIDA, WB, HMG, NISP
14	Rural Energy Policy	2006		✓						✓	✓	✓	✓		✓	✓	✓			✓	✓	GoN
15	Nepal Electricity Crisis Resolution Action Plan	2008	✓	✓					✓	✓	✓	✓	✓				✓	✓		✓		GoN
16	Ten Years Hydropower Development Plan	2009							✓	✓	✓	✓	✓		✓	✓		✓	✓	✓		MOWR/GoN
17	Subsidy Policy for Renewable (Rural) Energy	2009		✓						✓	✓	✓	✓		✓	✓	✓			✓		AEPC/GoN
18	Energy Sector Synopsis Report	2010	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓					WECS/GoN
19	Industrial Policy	2011					✓		✓	✓		✓	✓			✓	✓	✓				GoN
20	National Renewable and Rural Energy Program (2012–2017)	2012		✓						✓	✓		✓							✓		GoN
21	National Energy Strategy of Nepal	2013							✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		WECS/GoN
22	Renewable Energy Subsidy Policy	2013		✓						✓	✓	✓	✓		✓	✓	✓			✓		MoSTE/GoN
23	Nepal's Energy Sector Vision 2050 A. D.	2013	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		WECS/GoN
24	Renewable Energy Subsidy Delivery Mechanism	2013		✓						✓	✓	✓	✓	✓	✓	✓	✓					AEPC/ MoSTE/GoN
25	Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal	2014	✓						✓									✓	✓		✓	NEA, JICA, EPDC

TABLE A1 (Continued)

S. N	Policies	Year	Sectors: Domestic: Urban	Sectors: Domestic: Rural	Sectors: Transportation: Passenger	Sectors: Transportation: Freight	Sectors: Industrial & Commercial	Sectors: Others	Technologies: Hydropower: Large & medium (grid electricity)	Technologies: Hydropower: Small & micro	Technologies: Solar: Off-grid	Technologies: Solar: Grid connected	Technologies: Wind	Technologies: Hybrid	Technologies: Biogas: Household	Technologies: Biogas: Community	Technologies: Others	Demand side management & efficiency	Legal/ institutional arrangements	Promotion of private/ international sector collaboration	Focus on Research and Development	Involved organizations
26	Environment-friendly Vehicle and Transport Policy	2014			✓	✓			✓			✓		✓			✓		✓			MoPIT/GoN
27	National Sustainable Transport Strategy (2015–2040)	2015	✓	✓	✓	✓			✓									✓				MoPIT/GoN, UNCRD
28	Renewable Energy Subsidy Policy	2016		✓						✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	GoN
29	Biomass Energy Strategy	2017	✓	✓											✓	✓	✓		✓		✓	MoPE/GoN
30	National Renewable Energy Framework	2017		✓				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	AEPC/GoN
31	Whitepaper on Energy, Water and Irrigation: Present Situation and Future Prospect	2018	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MoEWRI/ GoN
32	National Energy Efficiency Strategy	2018	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MOFE/GoN
33	Renewable Energy Subsidy Delivery Mechanism for Special Program	2018	✓	✓						✓	✓	✓	✓	✓	✓	✓	✓					AEPC/ MoPE/GoN
34	National Action Plan for Electric Mobility	2018			✓	✓			✓										✓			MoFE/ MoPIT/GGGI
35	Hydropower Environmental Impact Assessment Manual	2018	✓						✓	✓												MOFE/GoN, IFC, ICIMOD, SDIP, GoJ
36	Industrial Enterprise Act	2020					✓		✓									✓	✓			MoITC/GoN
37	Energy Sector Synopsis Report 2021/22	2022	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓					WECS/GoN

(Continues)

TABLE A1 (Continued)

			Sectors						Technologies													
			Domestic		Transportation				Hydropower		Solar				Biogas					Promotion of private/ international sector collaboration		
S. N	Policies	Year	Urban	Rural	Passenger	Freight	Industrial & Commercial	Others	Large & medium (grid electricity)	Small & micro	Off-grid	Grid connected	Wind	Hybrid	Household	Community	Others	Demand side management & efficiency	Legal/ institutional arrangements		Focus on Research and Development	Involved organizations
38	Renewable Energy Subsidy Policy	2022		✓						✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	AEPC/ MoEWRI/ GoN
39	Renewable Energy Subsidy Delivery Mechanism	2022	✓	✓						✓	✓	✓	✓	✓	✓	✓	✓					AEPC/ MoEWRI/ GoN

Abbreviations: AEPC, alternative energy promotion centre; CIDA, Canadian international development agency; EPA, environmental planning associates; EPDC, electric power development company limited, Nepal electricity authority; GGGI, global green growth institute (Korea); GoJ, government of Japan; HMG, his majesty's government of nepalf; IFC, international finance corporation, international centre for integrated mountain development; JICA, Japan international cooperation agency; MoEWRI, ministry of energy, water resources and irrigation; MOFE, ministry of forests and environment; MoITC, ministry of industry trade and commerce; MoPE, ministry of population and environment; MoPIT, ministry of physical infrastructure and transport; MOPPW, ministry of physical planning and works; MoSTE, ministry of science, technology and environment; MOWR, ministry of water resources; NED, Nepal electricity department; NISP, Nepal irrigation sector project; SDIP, sustainable development investment portfolio, Australia; SMEC, snowy mountain engineering corporation; UNCRD, united nations center for regional development (Japan); UNDP, united nations development programme; WB, world bank; WECS, water and energy commission secretariat.

TABLE A2 List of policies with an overarching impact on the energy sector of Nepal from 1979 to 2022.

S. N	Policy documents	Year	S. N	Policy documents	Year
1	Seventh Plan (1985–1990)	1985	17	Forest Policy	2015
2	Eighth Plan (1992–1997)	1992	18	Fourteenth Periodic Plan (2016–2019)	2016
3	Industrial Enterprise Act	1992	19	First Nationally Determined Contribution	2016
4	Nepal Environmental Policy and Action Plan	1993	20	Forestry Sector Strategy (2016–2025)	2016
5	Ninth Plan (1997–2002)	1997	21	Sustainable Development Goals—Status and Roadmap (2016–2030)	2016
6	Local Self-Governance Act	1999	22	National Urban Development Strategy	2017
7	Forest Sector Policy	2000	23	Fifteenth Plan (2019–2024)	2019
8	Tenth Plan (2002–2007)	2002	24	Environment Protection Act	2019
9	Three Year Interim Plan (2007–2010)	2007	25	National Climate Change Policy	2019
10	Three Year Interim Plan (2010–2013)	2010	26	Second Nationally Determined Contribution	2020
11	National Adaptation Program of Action (NAPA) to Climate Change	2010	27	Environmental Protection Regulation	2020
12	Climate Change Policy	2011	28	Long Term Strategy for Net Zero Emissions	2021
13	National Framework on Local Adaptation Plans for Action (LAPA)	2011	29	Third National Communication to the UNFCC	2021
14	Thirteenth Plan (2013–2016)	2013	30	Environment-friendly Local Governance Framework	2021
15	Environment-friendly Local Governance Framework	2013	31	Urban Public Transport Management Authority Act	2022
16	Constitution of Nepal	2015			