Poverty Amidst Plenty: Renewable Energy-Based Mini-Grid Electrification in Nepal

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Abstract Providing access to electricity to a large section of rural population in Nepal has traditionally been a challenging exercise. This has been exacerbated by difficult geography, poor-socio-economic profile of rural Nepal and moreover by the on-going energy crisis. This chapter conducts an objective assessment of the renewable energy-based off-grid electricity sector in Nepal, with specific focus on micro-hydro-based mini-grid systems by applying a mixed method research design built on both qualitative and quantitative research techniques. While the country's experiences of developing micro-hydro- and solar energy-based off-grid interventions are captured by qualitative analysis, a standard techno-economic analysis of a micro-hydro mini-grid project is conducted to explore the possibility of introducing additional productive loads and to examine the cost efficacy of generating energy from micro-hydro vis-à-vis solar. Assessment of off-grid electrification options reveals that despite visible progresses, there still exist multiple

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roadblocks to scale up. Absence of clearly spelt out policy goals, weak institutional designs, low load factors, and lack of adequate finance and overall regulatory concerns stand as major obstacles for off-grid electricity sector development in the country. In addition, project-specific analysis reveals that solar loses out as a cost-effective option compared to micro-hydro. But optimal use of energy generated from micro-hydro-based mini-grids requires creation of productive applications at the local scale on a sustainable basis.

1 Introduction

Nepal, a land locked mountainous country of South Asia, is located between India and China. The country occupies a total land area of about 147,180 km^2 with a population of 30.5 million in 2011. About 40 % of the total land area of the country is covered by forests and shrubs. Country's socio-economic profile is not very encouraging as 44 % of country's population lives below poverty line [30]. The economy of Nepal is ranked as one of the slow growing economies by the World Bank [31], with per capita income of $742 and growth rate of 4.5 % during 2011–2012 [9]. About 82 % of country's population lives in rural areas. A large section (i.e. about 70 %) of population in Nepal is dependent on primary economic activities such as forests and agriculture, whereas the rest are engaged in secondary and tertiary sector activities. On human development front the performance has also not been encouraging. With a Human Development Indicator (HDI) of 0.463, Nepal is outranked by 156 countries [30]. Presence of political uncertainty and disruptive political activities are believed to have bred the debilitating and inefficient governance system and culture pervaded in all spheres of socio-economic life, including the energy sector in the country [15].

Providing access to energy in Nepal has traditionally been a challenging exercise. While at the global scale, about 1.2 billion people do not have access to electricity and about 2.6 billion people do not have access to clean cooking facilities [5], Nepal, being located in one of the least electrified regions of the World, i.e. in South Asia, has not escaped from this hard reality. About 7 million people (about 27 % of the total population) do not have access to any form of modern lighting energy [5]. Energy access challenges get exacerbated by geographical variations, poor transportability; scattered settlements, illusive energy development strategies, and lack of adequate capital [22]. Two pertinent aspects need further qualification. First, physiographic features of the country, as it has bearings on the state of energy system in the country and second, depth and intensity of on-going energy crisis, an outcome of multitude of factors like long persisting political instability, lack of adequate resources, and poorly crafted policy and regulatory framework.

Physiographic features of the country are characterised by rough physical terrain conjugated with a low, scattered and sparse population density. It is recognised at the policy sphere that providing grid electricity to all areas in Nepal seems to be a huge task in the country in the foreseeable future [12]. Grid-based centralised electrification system is considered to be relatively expensive and time-consuming to electrify scattered settlements located in difficult geographical terrains of the country [2, 3, 18]. Studies indicate that about 10 million people (which constitute about 33 % of the total population of the country) live in such remote locations requiring 5–18 days of walk to reach [34]. Marginal cost of grid expansion in Nepal is very high due to physical isolation, low electricity loads, and scattered low income consumers [8].

It is pertinent to highlight the persistence and deepening energy shortages the country has been experiencing since long, which has culminated into a 'great energy crisis'. Economic Survey of Nepal 2011–2012 acknowledges this on-going energy crisis in the country and states that "energy crisis has been the largest obstacle for country's economic development" [9]. The crisis gets embodied in multiple dimensions of energy supply, energy production, and energy consumption. It is posited that the energy crisis in Nepal gets accentuated by rapid urbanisation and growth of industries [16]. Load shedding of about 12–14 hours per day for almost all the on-grid households (about 2.4 million households are connected to the grid) is a clear manifestation of the magnitude of such a crisis. This high load shedding is often attributed to the poor power planning in the country resulting from inadequate capacity additions and growing electricity consumption in the country [27].

In the above backdrop, this chapter focuses on off-grid electrification development in Nepal, with a specific thrust on micro-hydro-based mini-grid systems. Though recently Nepal has decided to go for solar mini-grids for electrification, it has not yet been physically taken up; therefore we have not considered solar mini-grids in our analysis. The analysis dwells on the following set of research objectives.

- Assesses the state of renewable energy-based off-grid electrification in Nepal.
- Presents a critical evaluation of policy and institutional landscape governing the renewable energy-based off-grid electrification in Nepal.
- Conducts a techno-economic analysis of a micro-hydro mini-grid project to explore the possibility of introducing additional productive loads and to examine the cost efficacy of generating energy from micro-hydro vis-à-vis solar.
- Discusses key aspects of and identifies key anomalies and distortions for off-grid electrification in Nepal.

The chapter is organised as follows. Section 2 spells out the study approach. Section 3 presents the macro energy scenario in Nepal. Section 4 highlights the renewable energy-based off-grid interventions in Nepal. Section 5 dwells on the policy, regulatory and institutional contours governing off-grid electrification in Nepal. Section 6 discusses the key elements of off-grid electrification in Nepal. Section 7 presents techno-economic analysis of a micro-hydro-based mini-grid project. Section 8 carries out a critical assessment of off-grid electrification by identifying the key anomalies and barriers. Section 9 offers some policy recommendations and the final section concludes the chapter.

2 Study Approach

The triangulation method of research design, built on both qualitative and quantitative research techniques, has been employed for the analysis. The method prioritises collecting, analysing and mixing both quantitative and qualitative data at different phases in the research cycle. While the emphasis of qualitative approach is to understand the critical nuances, actors and institutions associated with and processes involved with the off-grid energy development in Nepal, quantitative assessment supplements the qualitative analysis by carrying out critical evaluation of the primary and secondary information, gathered as part of the study.

A week-long visit was conducted in Nepal to carry out the survey and to gather information for the study. The survey was divided into two parts. First, key informant interviews were conducted with different stakeholders such as government officials, donor agencies, NGOs, various associations, researchers, private entrepreneurs and system manufacturers, bank officials to understand and assess the state of renewable energy-based off-grid electrification system in the country. Second, a field visit to a micro-hydro site was carried out to gather information about the project operation, management and aspects of project sustainability and to validate the findings from key informant interviews.

A host of data collection techniques namely research interviews, field research, stakeholder's analysis and focus group discussions (FGDs) were used to elicit the desired set of information. A semi-structured interview format with flexibility to accommodate changes was administered to conduct interviews with different stakeholders to obtain information. Interviews at the micro-hydro project site constituted transect walks, FGDs, and observational data gathering and semi-structured interviews with key local informants such as system technician, president of the management committee, village chief, school teachers, village shop keepers, productive end-users, and local health clinic staff. In order to identify the prospective stakeholders, a non-probabilistic purposive sampling method was used to select interviewees having knowledge and understanding of off-grid renewable energy in the country and having direct and indirect association with the sector. Key stakeholders interviewed are listed in the Annexure (Table A.1). The interview conducted was aimed to understand the multiple crucial dimensions of off-grid electricity sector development in Nepal such as growth and trend of renewable energy centric rural electrification, role of donor agencies, policy level supports and issues related to the subsidies and incentives, financial mechanisms, role of associations, NGOs and civil societies. The gathered information from multiple stakeholders that was recorded and coded for further analysis. Information gathered from field visits were used to carry out a comparative financial assessment of various electrification options for Nepal.

3 Macro Energy Setting in Nepal: An Overview

Nepal is one of the countries with lowest per capita electricity generation and consumption. Per capita energy consumption stood at 103 kWh in 2010 [31]. Total generation capacity of the country is about 714 MW [32], largely drawn from hydro sources. The energy sector in the country is characterised by slow growth in all the critical dimensions. International Energy Agency (IEA)'s Energy Development Index[1] (EDI) for Nepal ranks the country at 74 in 2012 with an EDI score of 0.08, echoing the poor state of energy development in the country [5]. State of energy access in Nepal exhibits the presence of heterogeneity in access to different forms of energy (Fig. 1). While overall electrification rate in Nepal is about 75 %, there exist wide disparities in electrification rates between urban and rural areas. 94 % of urban areas use electricity for lighting compared to 61 % in rural areas. About 22 % of rural households in Nepal rely on kerosene as their prime source of lighting. In addition, solar, largely in the form of solar home systems (SHSs) has also emerged as a potential alternative source of lighting energy and about 9 % of the rural households are using solar as a source of lighting [19]. This urban-rural disparity worsens when it comes to access to modern energy for cooking. Use of traditional biomass for cooking reveals that while 27 % of urban population rely on fire wood and cow dung for their cooking, the corresponding figure is 86 % for rural areas in Nepal [14].

Despite Nepal being the second hydro resource rich country after Brazil and having enormous potential for solar energy, three decades of research and development has not produced visible progress. In terms of availability of water resources, the country is endowed with around 6,000 rivers and rivulets with a theoretical potential of approximately 85,000 MW electricity generation capacities. Similarly, Nepal is also endowed with adequate solar resources with average radiation of 4.7 kWh m^{-2} day^{-1}. However, available hydro and solar resources have not been exploited optimally so far in the country. The electricity generation capacity of Nepal has remained almost stagnant for the last 20 years. This stagnation has resulted largely due to failure in completing the hydro project construction and commissioning in due time [27] and inadequate attention of donor agencies for the promotion of large-scale hydropower development of the country. In addition, the country has not been able to attract investors in this sector despite the liberalised environment created with the enactment of Hydro Power Development Policy 1992 [29]. On the other hand, rapid urbanisation and industrialisation has led the electricity demand to peak at 946 MW in 2011 and predicted to increase to 3,679 MW in 2027–2028 [13].

[1] Energy Development Index (EDI) of International Energy Agency (IEA) helps in understanding the role of energy in promotion of human development of a country [5]. It is constructed by a set of four indicators i.e. per capita commercial energy consumption, per capita electricity consumption in the residential sector, share of modern fuels in total residential sector energy use and share of population with access to electricity.

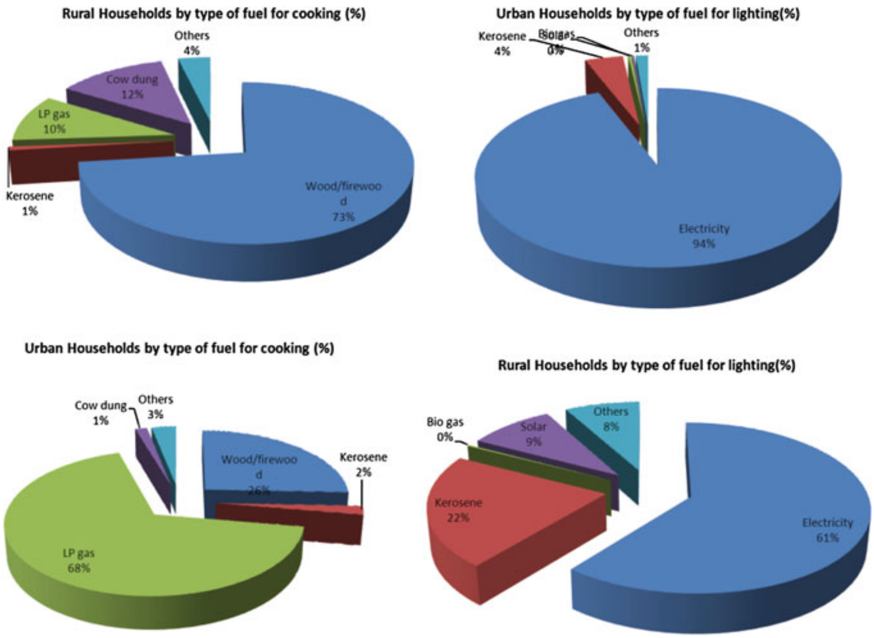

Fig. 1 Cooking and lighting energy scenario in urban and rural conurbations in Nepal. *Data source* Nepal Living Standard Survey [14]

In order to get a better picture of the state of energy scenario in Nepal, we present energy access index[2] for different districts in Nepal by combining access to electricity indicator and access to clean cooking fuel indicator as well as both the indicators separately for all the 75 districts in Nepal. It could be gleaned from Fig. 2 that clusters could be identified where high access to electricity is accompanied by high access to clean cooking energy and vice versa. However, there exist contrasting combinations suggesting specific policy thrusts on individual dimensions of access to energy.

The macro energy scenario in Nepal indicates the dismal state of energy availability and energy use. There exist enormous challenges of access to modern lighting and cooking energy. More importantly, given the limitations of the grid electrification system in the country, large sections of the rural population are still devoid of any form of modern energy. In view of this, renewable energy-based off-grid electrification options are now being prioritised as a supplementary route to the grid-based system. The following section dwells on the off-grid electrification systems in the country.

[2] We largely follow the methodology advocated by IEA for constructing such an index. However due to paucity of data, we have limited only to household level indicators of IEA. Variables are normalised applying the standard normalisation process. Equal weights to each individual indicator are assigned to construct the index.

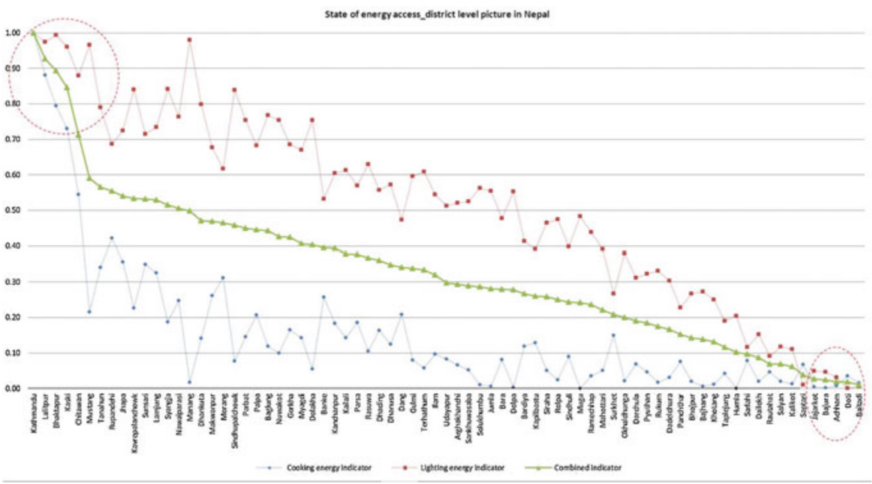

Fig. 2 State of energy access across districts in Nepal. *Data source* Nepal Living Standard Survey [14]

4 State of Off-Grid Renewable Electrification in Nepal

Development of alternative energy systems in Nepal could be traced back to the early 1970s. The off-grid renewable energy sector in Nepal has experienced a phased development process [23]. The initial focus was on adaptive research and technology transfer, followed by emphasis on pilot programmes and developing ad hoc policies for the promotion of renewable energy development during 1980s and 1990s. Next, emphasis was laid on setting targets, policy formulation, planning, resource allocation, capacity building and institution strengthening during 1990–2010, and the final phase was the period of scaling up, envisaging public–private-partnership (PPP) models, emphasising sectoral development, increasing the share of renewable energy in energy portfolio, linking energy with economy, upgrading technology, making coherent policies and linking with the environment [23].

Off-grid electrification is mainly targeted at electrifying remote rural areas of the country characterised by low population density, low load factor and geographical remoteness. In addition, on-going energy crisis also gave impetus for the greater use and exploitation of off-grid renewable energy resources of the country [4, 28]. Micro-hydro, pico-hydro, and SHSs are the preferred modes of off-grid electrification in Nepal, though a small amount of electricity is generated through small-scale wind energy systems. There exist about 3 million off-grid households in Nepal, out of which 97 % are in rural areas. About 12 % of the total population is electrified through renewable energy-based off-grid energy systems. While 22 MW generation capacities have been installed through micro-hydro and pico hydro schemes, 12 MWp capacities have been installed through solar PV schemes. Besides, micro-hydro, pico hydro and solar, about 20 kWe is generated through wind energy systems as well [1].

History of micro-hydro-based mini-grid systems in Nepal is the oldest and goes back to the early 1960s and being constantly developed since then. Initial focus of micro-hydro-based mini-grids was to create livelihood opportunities by utilising the electricity for agro processing and other allied activities. Gradually, micro-hydro-based mini-grids became a source of community electrification. These micro-hydro systems, during early days, were small in capacity ranging between 5 and 20 kW and largely supported by international donor agencies. These systems were providing lighting requirements with some productive activities like grinding, husking and oil-expelling. This was followed by installation of large-scale hydro-electric systems during mid-1980s. Development of micro-hydro systems was further accelerated through provision of loans and technical assistance and subsidies provided during early 1980s. It was further boosted by financial and fiscal incentives such as subsidies; supports extended through several donor agencies and a host of other factors. As per recent statistics, there are about 999 micro-hydro-based mini-grid systems constituting about 19 MW and about 1,480 pico-hydro projects totaling about 3.18 MW deployed by 2012. As far as the ownership of micro-hydro mini-grid projects are concerned, 95 % of the projects are community owned; whereas about 5 % are privately owned and a few are owned by the National Electricity Authority (NEA) [3].

Two major programmes supporting the development of micro-hydro mini-grid projects in the country are (1) Energy Sector Assistance Programme (ESAP) supported by DANIDA, KfW, DFID and Norwegian Government and (2) Rural Energy Development Programme (REDP) supported by UNDP and World Bank. While ESAP supported installation of about 290 micro-hydro mini-grid projects and about 402 pico-hydro projects, under REDP more than 300 micro-hydro mini-grid projects ranging from 10 to 100 kW have been deployed [1, 25]. Figure 3 portrays cumulative number of households connected and kW capacity of micro-hydro projects installed under the ESAP programme.

5 Policy, Regulatory and Institutional Contours

The need and significance of policies and institutional considerations has been highlighted by several scholars and experts. It is emphatically posited that deployment of off-grid renewable energy technologies requires concrete and plausible policies [17]. Potential to upscale renewable systems largely hinges on the country's institutional characteristics and policy landscape governing the sector [16, 33]. This section highlights the existing policy and institutional landscape governing the off-grid renewable energy sector in Nepal. Planned development process in Nepal also has recognised the importance of renewable energy-based off-grid systems in the country starting from the declaration of Seventh Development

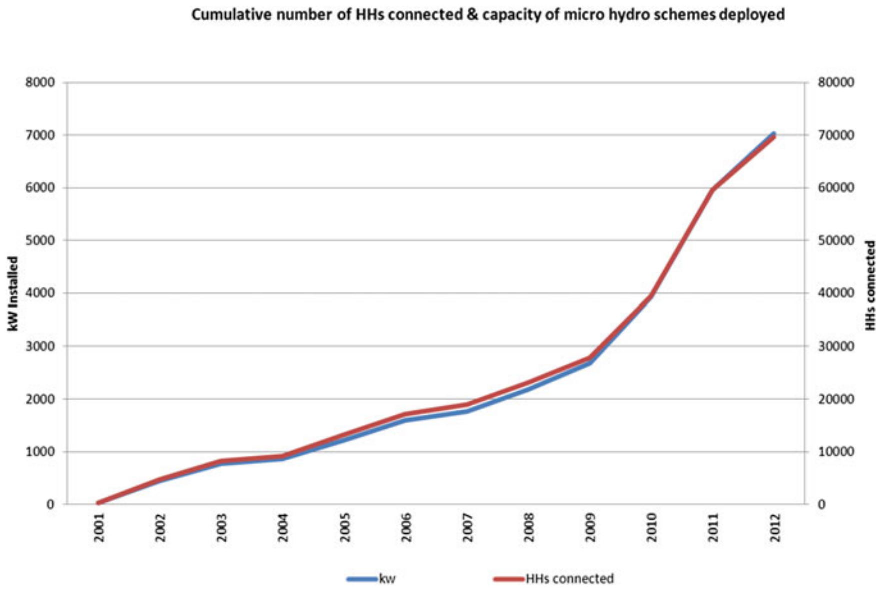

Fig. 3 Cumulative number of HHs connected and capacity (kW) deployed under ESAP programme, *Data source* AEPC [1]

Plan (1985–1990). A snapshot of the planned development process and its focus on renewable energy-based off-grid energy development in the country is presented in the Box 1.

Box 1: Planning process in Nepal and focus on renewable energy-based off-grid system development

The planned energy development in Nepal started with the declaration of Seventh Development Plan (1985–1990) with specific thrust on conservation of forest resources and upliftment of rural economy of the country. The Plan emphasised on the promotion of biogas, solar thermal, wind energy, improved cook stoves, small water turbines and improved water mills. Specific focus was laid on research and development aspects and tapping of private sector potential in the field. Priority is also assigned to incentivising the sector by giving grants and loans for large-scale dissemination of off-grid energy systems.

The Eighth Plan (1992–1997) continued its focus on renewable energy drawing from the experiences gained from the Seventh Plan. Specific thrust was laid on developing technical manpower and gathering basic data for development of biogas, solar energy and wind energy. Increase in use of solar-based systems like solar water heater, solar dryer, solar cooker, solar pump, solar generator, solar photovoltaic cells was prioritised. Emphasis was

laid on attracting private investors. The plan proposed to develop a master plan for the diversification of use of solar energy. It declared a special provision for subsidies for PV household systems.
Ninth Plan (1997–2002) reiterated the need to develop renewable energy as an important element of national development agenda by putting emphasis on the creation of employment opportunities, improving rural livelihood conditions and prioritising environmental sustainability. Research and development was also kept high on the agenda to cut down the cost of generating power from alternative sources of energy.
Tenth Plan (2002–2007) laid emphasis on exploiting solar energy to meet the mounting energy demand. In addition, the need to electrify remote and rural areas through solar-based interventions was also assigned primacy. The Plan envisaged setting up of Rural Energy Fund (REF) to manage and channelise grants and loans for development of alternative energy systems in the country.
First 3 Year Interim Plan (2007–2010) focused on developing a long-term alternative energy agenda for the country with specific thrust on development of rural areas, creation of employment opportunities and sustainable development of the sector. Second 3 Year Interim Plan (2007–2010) set an ambitious target of procuring 10 % of energy from alternative sources.

Policy pronouncements for off-grid energy development in Nepal could be traced back to the declaration of Hydro Power Policy 1998, reformulated in 2001. Hydro Power Development Policy 2001 placed emphasis on development of rural economy through energisation and creation of favourable ground for private investors by devising appropriate policies and incentive schemes. One of the important policy initiatives in the off-grid sector was undertaken with declaration of Rural Energy Policy (REP) in 2006. This Policy prioritises access to clean, reliable, and appropriate energy in rural areas. The Policy sets the objective of reducing dependency on traditional sources of energy, conserving environment, generating employment and creating productive activities through development of rural energy resources. Priority is also laid on creating capacities, human resource development, strengthening local institutions and tapping private sector capabilities.

In addition to above policies, specific policies and mechanisms have been spelt out from time to time to disburse subsidies. First National Subsidy Policy 2000 envisaged providing subsidies to SHSs, and solar water pumps. Subsidy Policy 2009 broadened the scope by not only providing subsidies for SHSs and solar water pumps, but also extending subsidies to institutional solar PV systems. The Policy aimed at maximising service delivery and providing opportunities to the low income households in the rural areas, making use of grant assistance, and supporting and extending renewable energy markets. The new subsidy policy, i.e. Subsidy Policy 2013, inter alia, has set objectives like reducing cost of supply, encouraging productive use of energy, developing markets for renewable energy and contributing to the better health and education of people. In line with subsidy policies, subsidy delivery mechanisms are declared from time to time. For instance, while Subsidy Delivery Mechanism 2006 has spelt out the need for disbursing subsidies in a cost effective and easy access manner for the acceleration of renewable energy market, the Rural Energy Subsidy Delivery Mechanism 2010 has emphasised on setting subsidy criteria for various renewable energy resources and delivery mechanisms for disbursement of subsidies for different forms of renewable energy-based off-grid energy sources.

Thrust on promoting alternative energy in Nepal has also been recognised through several other policy pronouncements. For instance, National Adaptation Programme of Action (NAPA) of Nepal, 2010 has identified a list of priority adaptation options for the energy sector. Specific thrust was assigned on the promotion of alternative energy technologies and strengthening the institutional aspect of promoting alternative energy technologies [11]. Apart from policies, promotion of off-grid renewable energy sector is also done through several other fiscal and financial incentives such as exemption of taxes, reduction of tax amounts, etc.

While legal and policy systems of the country are designed to govern the sector, the state of institutional artefacts shape the system of governance of a country to a great extent. Organisational contours for off-grid energy sector in Nepal reveal a complex web of interrelationships between multitude of actors and entities.[3] At the ministerial level, the task is to formulate, implement, monitor and evaluate policies, plans, programmes. It is also the duty of the Ministry to carry out research and development activities, promote private sector participation in the sector and to deal with multilateral agreements. At the institutional level, Alternative Energy Promotion Centre (AEPC) being at the helm of the affairs of off-grid and renewable energy development in the country, is responsible for mainstreaming renewable energy-based interventions in the country. Created in 1996, AEPC is

[3] These actors and entities consist of a couple of ministries like the Ministry of Science, Technology and Environment (MoSTE) and the Ministry of Energy (MoE), several government originations and institutions like the National Planning Commission (NPC), the Water and Energy Commission Secretariat (WECS), Alternative Energy Promotion Centre (AEPC), Renewable Energy Test Station (RETS), several donor agencies e.g. Danish International Development Agency (DANIDA), European Union (EU), United Nations Development Programme (UNDP), Norwegian Government, Bank Aus Verantwortung (KfW), Department for International Development (DFID) of UK Government, Asian Development Bank (ADB), a couple of associations like the Nepal Micro-hydro Development Association (NMHDA), and the Solar Electric Manufacturers Association of Nepal (SEMAN), banking and credit lending institutions the Clean Energy Development Bank Limited (CEDBL), the Himalayan Bank Limited (HBL), and the Lakshmi Bank Limited (LBL) and a number of manufacturing and installation companies, NGOs, micro-finance groups, local NGOs, village co-operatives, research institutes and many more.

entrusted to carry out research and development for the promotion of renewable energy-based off-grid systems in the country, to manage and administer subsidy policies, and to act as an umbrella organisation for several other activities and initiatives such as UNDP led REDP, Danish and Norwegian Co-funded ESAP, and European Union funded Renewable Energy Project (REP) and Rural Energy Fund. The Centre has been responsible for the formulation of plans and policies, mobilising resources, monitoring and coordinating activities, keeping check on quality and executing all other necessary activities. AEPC also has local functionaries at the level of districts, namely District Energy and Environment Sections/Units and Regional Renewable Energy Service Centres (RRESC) to execute activities at the district level. There are also affiliate institutions like Renewable Energy Test Station (RETS), which conducts various quality tests of renewable energy products and qualifies companies to receive subsidies and get tax waivers.

Various donor agencies and organisations have been playing an instrumental role in off-grid energy development in Nepal supporting several off-grid renewable energy programmes. The focus and thrust of donor funded programmes differ and is largely driven by the guidelines and philosophies of donor countries. However, there seems to be lack of co-ordination and harmonisation among these donor funded programmes thereby often duplicating the efforts. Of late, efforts have been undertaken by AEPC to bring all the donor funded programmes under one umbrella through National Rural and Renewable Energy Programme (NRREP).

Of late, private sector banks have emerged as an effective channel to finance various off-grid renewable-based interventions in Nepal through innovative financing schemes. While public sector banks like Agricultural Development Bank Limited (ADBN) of Nepal was involved in micro-hydro project financing as early as 1980, several private sector banks such as Clean Energy Development Bank Limited (CEDBL), Himalayan Bank Limited (HBL), and Lakshmi Bank Limited (LBL) have recently ventured into the off-grid renewable energy space through various financing schemes. Some of these banks have set up separate dedicated cells to finance the energy projects. Banks are also entrusted responsibilities by donor agencies to manage special funds meant for promotion of off-grid electricity sector in Nepal. For instance, CEDBL and HBL are tasked to manage Micro-hydro Debt Fund which is supported by GIZ and anchored through AEPC. HBL has been able to finance six micro-hydro projects[4] through Micro-hydro Debt Fund scheme. Banks also act as financing agents for private renewable energy developers and energy service companies. For instance, CEDBL has financed four hydro power contractors, 8 micro-hydro installer companies, 28 solar companies, 6 biogas construction companies.

[4] These micro-hydro projects are Khani Khoka (20 kW) in Karve dirtict, Chari Tola (80 kW) in Ramechhap Dictrict, Thulo Khola (50 kW) in Okhaldhunga District, Swara Tap Khola (30 kW) in Khotang District, Lumju Khola (20 kW) in Khotang District, Midim Khola (100 kW) in Lamjung District [24].

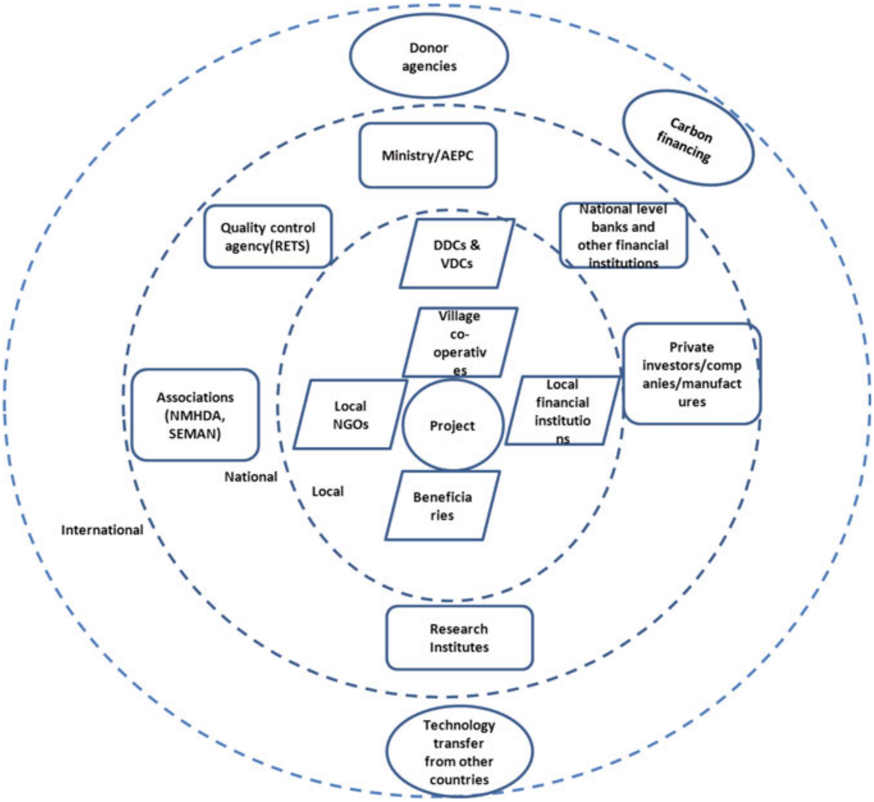

Fig. 4 Institutional contour governing renewable energy based off-grid energy system in Nepal, *Data source* Construed by authors

Associations formed by private companies like Nepal Micro-hydro Development Association (NMHDA), and Solar Electric Manufacturers Association of Nepal (SEMAN) also play a crucial role in driving the off-grid electricity sector in the country by creating necessary skills, expertise and by protecting the welfare of these private companies. General concerns of manufacturers and companies are addressed through these associations. These associations also conduct periodic training and capacity building programmes on various issues of importance. Apart from all of the above, there exist a number of research institutes and universities, private companies, NGOs, micro-financing institutions, village co-operatives contributing to the development of off-grid renewable energy systems in the country. A graphical exposition of various institutions and organisations placed at different scales governing the renewable energy-based off-grid energy sector in Nepal is presented in the figure below (Fig. 4).

6 Salient Features of Renewable Energy-Based Mini-Grid Systems in Nepal

This section analyses key features of renewable energy-based mini-grid electrification in Nepal.

6.1 Service Delivery Models

The dissemination of mini-grid projects in Nepal is done through a variety of delivery models. In majority of the cases, delivery models hinge upon the specific programme features and characteristics under which the project was developed. Deployment of micro-hydro-based mini-grid systems is largely done through community-managed delivery systems, albeit, in some cases by private entrepreneurs. In addition, private entrepreneurs also play an important role even in community-managed projects. Private manufacturing companies and private installer companies carry out the task of surveying, designing, installation of systems. These companies are pre-qualified by AEPC to channelise subsidies to the communities. Often deployment of projects largely follows programme protocols and guidelines. For instance, while Energy Sector Assistance Programme (ESAP) lays emphasis on improving the living conditions of the rural people through enhanced access to energy, Renewable Energy Development Programme (REDP) assigns primacy to community mobilisation aspects. Apart from community managed mini-grid schemes, other prevalent type is the private sector promoted projects, which constitutes about 5 % of the total mini-grids deployed [3].

6.2 Operational Modalities

Implementation of mini-grid projects in Nepal has been carried out through a public–private-partnership model. While the public sector performs several pertinent activities like capacity building, providing technical and financial assistance, and instituting mechanisms for quality control, private sector spearheads in manufacturing, supply and installation, after-sales service and internal quality checks. The first step is to identify the project site and then carry out demand assessment for such a project. Demand assessment is done through a scientific process of mapping by using the GIS tools and techniques. Next phase is the project approval phase, where the project gets approved at various stages through a structured approval system in place. The most immediate approval is required from District Development Committee (DDC)/Regional Renewable Energy Service Centres (RRESC), and then it gets approved by AEPC, where the project details are reviewed by a technical team known as Technical Review Committee

(TRC). Once it gets approved by the TRC, projects finally get in-principle approval for subsidy support. This is followed by installation and commissioning of the project. Once the project is installed and implemented, it goes through a quality control process. First level of quality control is in terms of monitoring and inspection of the project under construction. Next level of quality checking is done during testing and commissioning of the project. Final level of quality control is done through power output verification. As a process of quality check, 1 year guarantee is ensured by the project developer and consultant and 10 % of the project cost is kept as security money.

6.3 Financing of Projects

Project financing structures reveal some interesting patterns. In case of micro-hydro mini-grids, finance is mobilised through four major sources, e.g. government subsidy, community equity, contribution from local governments and contribution from other organisations.

In majority of the cases, subsidies from the Government of Nepal and donor grants constitute about 50 % of the project cost; of course variations exist depending on remoteness of the project area. The District Development Committees (DDCs) and the Village Development Committees (VDCs) contribute in terms of equity investment which is about 10 % of the total project costs; Rest of the amount is contributed by communities both in cash and kind terms. Contribution of communities in kind (in terms of labour and locally available construction material) constitutes 20 % of the total project cost and financial contribution by communities, either in the form of cash and/or bank loans forms rest 20 % of the project costs.

Subsidies have been instrumental in mainstreaming the renewable energy dissemination and wide scale deployment of micro-and pico-hydro projects and solar home systems (SHSs). Subsidy disbursement mechanisms are spelt out by the Government from time to time. Important aspect of this subsidy disbursement mechanism is the graded subsidy provisions based on the remoteness of the location. For disbursement of subsidies, VDCs have been grouped into different classes such as ‘category A’ VDCs, ‘category B’ VDCs and ‘category C’ VDCs on the basis of their remoteness, starting from very remote VDCs to accessible VDCs, respectively.

In order to enhance the access and instil a sense of commercialisation among the beneficiaries of mini-grid systems, innovative financing mechanisms have been devised by banks through support from multilateral and bilateral agencies and organisations. Micro-hydro Debt Fund—a dedicated fund to finance micro-hydro projects within the range of 10–100 kW has been operationalised by GIZ/AEPC. The funds have been routed through banks engaged in promotion of renewable energy in Nepal. GIZ/EnDev (German/Deutch collaboration) and NORAD have been supporting this initiative. For example, the Micro-hydro Debt Fund has a portfolio of €500,000 that is available for soft loan for micro-hydro projects. An additional €42,000 (in the form of technical assistance) is available for capacity building of local institutions, AEPC and rural communities. As mentioned in the previous section, loans from the fund are channelled through two banks, namely CEDBL and HBL of Nepal. Under this scheme, a maximum of 40 % debt financing is provided.

In majority of cases, decisions on tariff are made by the user committees. There are four major varieties of tariff structures prevailing in community managed mini-grid projects. These are largely monthly charges per household, monthly charges per bulb, charges based on per watt per month, and charges based on per unit (kWh) per month. Tariff rates are designed to meet the O&M cost of the project.

Of late, thrust has also been laid on carbon financing schemes, as an additional source of finance, to enhance the financial viability of projects. It is reported during the survey that about 650 micro-hydro-based mini-grid projects have been bundled by AEPC and registered in order to procure carbon financing. These projects are expected to generate about 40,535 tonnes of CO_2 emissions.

6.4 Quality Control Mechanisms

Another crucial dimension of renewable energy-based mini-grid development is the system of quality control. In order to ensure better quality of renewable energy products in the country, various quality control mechanisms have been put in place. For instance, disbursement of subsidies is linked to maintaining minimum standards of quality of renewable energy products and equipment [23]. Renewable Energy Test Station (RETS) has been created as a quality control arm of AEPC to ensure quality of renewable energy products and equipment. As of now, RETS has been primarily looking after the quality of photovoltaic-based systems as per the guidelines laid down in the Nepal Photovoltaic Quality Assurance (NEPQA) standard. Quality control of photovoltaic systems is done at three different stages, i.e. during pre-installation, during installation and post-installation stage. Quality control of micro-hydro-based mini-grid projects in Nepal is largely carried out directly by AEPC through periodic monitoring and evaluation of projects. For instance, Monitoring and Quality Assurance (MQA) Unit has been created within the technical support component of the recently launched National Rural Renewable Energy Programme (NRREP)[5] of AEPC. Lately, RETS has also been assigned the task of checking the quality of micro-hydro equipment and products.

[5] NRREP is a joint programme of Government Nepal and multiple donor agencies which brings all the individual programmes supported by multiple donor agencies under one umbrella and is executed by AEPC.

However, due to limited financial resources available at the disposal of the RETS, there has been limited progress achieved in terms of ensuring quality renewable energy products and equipment.

6.5 Capacity Building Efforts

Capacity building has always been considered a critical aspect for the sustainability of off-grid energy interventions. Capacity building is done through various ways and for different stakeholders. An important aspect of this capacity building effort is technical assistance schemes provided under various donor funded programmes. Major donor supported programmes such as ESAP and REDP have technical assistance components, seek to develop necessary knowledge and skill sets required for the operation and management of the systems. Technical support is provided through training, information, guidelines and quality assurances. In addition, enhancing the strength and ability of rural communities is also prioritised by several donor agencies. For instance, REDP programme gives emphasis on community mobilisation and communities are placed at the centre of the project operation, management and sustainability. Community mobilisation is considered pivotal and an important step in the project initiation process. Community mobilisation under REDP consists of organisation development, skill enhancement, capital formation, technology promotion, environment management, and empowerment of vulnerable groups.

Capacity building activities are also carried out by private associations like NMHDA and SEMAN. These associations conduct periodic training and capacity building programmes to build skilled manpower for the acceleration of off-grid renewable energy programmes in Nepal in association with AEPC under various donor funded programmes. For instance, Nepal Micro-Hydro Development Association (NMHDA) has been conducting surveyors training, managers training, quality and management aspects of MHP for installers, auto-cad training, output verification training, end use promotion training, operators training, advanced operators training and operators refresh training for last 10 years or so. NMHDA has conducted 42 training sessions till 2012. Importantly, these training and capacity building activities are supported by various donor-funded programmes like REDP, ESAP and RERL. The training and capacity building programmes of NMHDA have been able to generate a pool of skilled manpower to manage the micro-hydro-based mini-grids in Nepal. For instance, 44 operator trainings conducted by NMHDA since 1997 have trained around 883 numbers of skilled micro-hydro operators in the country.

The above discussion brings out succinctly various aspects of renewable energy-based mini-grid systems in Nepal. It is evident that adequate measures have been taken in terms of creating necessary institutions, devising policy and incentive schemes, maintaining quality and building capacities to promote renewable energy-based mini-grid systems in the country. However, it would be more interesting to delve deep into the operational artefacts of mini-grid development in Nepal by conducting an in-depth analysis of a micro-hydro-based mini-grid project. The next section conducts such an analysis.

7 Case Study

In order to supplement the discussion above, we present here a case study drawing from the information gathered from our field visits and stakeholder interviews. While assessing the case study, we largely follow the framework suggested by Mishra and Sarangi [10] for mainstreaming renewable energy-based off-grid systems in developing countries.

The project, selected for the study, is located in Mahadevstan VDC in the Dhading district of Nepal. The project is serving about 265 households, out of which about 80 % are poor, and about 13 % are middle-income households and rest are rich households. Project cost decomposition reveals that about 75 % of cost of the project was covered through government subsidies, whereas the rest amount was mobilised in the form of private equity (both cash and kind), loans and contributions from local government, i.e. VDC and DDC. It must be noted here that since the project was supported by UNDP and World Bank funded Renewable Energy Development Programme (REDP), implementation modalities of this project largely follow the REDP programme guidelines. The details of the studied project are given in the Table (Table 1).

As suggested by Mishra and Sarangi [10], the very first task towards deployment of mini-grid system would be to carry out a needs assessment survey. It was revealed from our discussion with various stakeholders that a proper demand assessment was conducted as an important initial activity for the project installation. However, since REDP emphasises on mobilising communities as a pre-requisite for deployment of micro-hydro projects, the very first step undertaken was to form users committees and strengthen the community capability for the effective operation and management of the project. Once the user committees were formed, application was submitted through proper channel to DDC/RRESC and finally to AEPC. Second most important step carried out was the project identification, where a potential project site was identified through a scientific process by applying the GIS tools/techniques. The GIS mapping and detailed feasibility study (DFS) suggested the possible capacity of the project, monthly flow of water, catchment area with its land use type, geo-references position of major structures like intake, settling basin, fore bay, and power house, headrace canal, and penstock pipe length, and their head losses, the transmission lines and its segments and length. Next step was the project approval phase, where the project got approved through a structured approval system in place. The most immediate approval was received from DDC/RRESC, and then it got the approval from AEPC, where the project details were reviewed by a technical team known as Technical Review Committee (TRC). Finally, the project got in-principle approval for subsidy.

Table 1 Salient features of the project

Name of the project	Malekhu Khola
VDC	Mahadestan
District	Dhading
Capacity	26 kW
Number of HHs	265
Year of commissioning	2007

Source From the field

Since, the resource mapping at the community scale was only limited to micro-hydro schemes; it did not consider other potential resources. However, following Mishra and Sarangi [10], we have compared unit cost estimates of energy of the present technology with other technologies. Since, micro-hydro and solar are the key technologies used in Nepal for rural electrification [6, 20], we have limited our comparison to these two important technologies. In order to get a comparative picture of micro-hydro vis-à-vis solar energy, we estimated the levelised cost of electricity (LCOE)[6] for the micro-hydro project under consideration and a similar size solar PV project. Our analysis suggests that for same capacity plant, while LCOE for micro-hydro plant is coming out to be 0.07 USD, LCOE for solar plant is estimated to be 1.01 USD. Our findings are corroborated with the findings of the Mainali and Silveira [6], where authors have estimated that LCOE for solar projects ranges between 0.55 and 1.01 USD. The detailed parameters and estimated LCOE figures are presented in the table below (Table 2).

In addition, we also attempted to compare and contrast the existing case (base case) with possible scenarios with increased productive loads to examine the possible extent of unit cost reduction. Apart from the base case, we have envisaged three different scenarios based on increased productive end uses. This increase in productive loads is based on the assumptions taking into consideration the socio-economic profile of the villages being presently served by the project. This has been done primarily on the basis of recent concerns about low capacity utilisation of micro-hydro projects in Nepal due to poor productive end uses [3]. Load profiles for base case and different scenarios are presented in the Table 3 and Fig. 5.

It is evident from the table below (Table 3) that in the scenario 1 (S1) as we increase the productive load from 14 to 17 kW; LCOE comes down from 0.07 to 0.066 USD. In case of scenario 2 (S2), a further increase in the productive load by increasing the number of hours of productive end uses leads to further reduction in LCOE to 0.061 USD. Finally, in scenario 3 (S3), we have increased the productive load to 22 kW; this gives rise to further reduction in LCOE to 0.057 USD.

[6] For analysing the levelized cost of electricity (LCOE) one has to consider the total life time cost of the project which includes the capital costs, operation and maintenance costs, replacement cost, fuel cost and the environmental externalities costs and total electricity produced by the plant during its lifetime. The formula for estimating LCOE is, $\text{LCOE} = \frac{\text{Total life time cost of the plant}}{\text{Total life time useful electricity produced}}$.

Table 2 Parameters for LCOE for 26 kW MHP and SPV plant

Parameters	MHP	SPV
Rated power capacity (kW)	26	26
Annual power generation (kWh)	51,496[b]	34,164
Life span of the plant (years)	15	20
Escalation factor (%)	5	5
Loan interest rate (%)	12	12
Inflation rate (%)	5	5
Emission factors (g/kWh)	0.01 (NO_x), 0.01 (SO_x), 5.92 (CO_2)	0.193 (NO_x), 0.322 (SO_x), 83.43 (CO_2)
Marginal external/damage cost ($/kg)[a]	1.5312 (NO_x), 5.8080 (SO_x), 0.0277 (CO_2)	1.5312 (NO_x), 5.8080 (SO_x), 0.0277 (CO_2)
Capital cost of the plant ($)	53937.00[b]	93600.00
Annual O&M cost ($)	1300.00[b]	2100.00
LCOE ($/kWh)	*0.07*	*1.01*

Source [a] Mainali and Silveira [6]; [b] From field surveys (Currency conversion rate: 1 USD = 80 NCR)

Financial efficacy of the project is also analysed by carrying out sensitivity analysis. Sensitivity analysis for the changing subsidies and its impact on LCOE is presented in the figure below (Fig. 6). It is evident from the figure below that with zero subsidy, the estimated LCOE is very high. However, micro-hydro is still financially attractive compared to the solar PV project.

It is evident from the analysis above that though micro-hydro is a cheaper option compared to solar PV; the challenge is to bring down the cost of supply by creating additional productive loads, which has been a concern in majority of off-grid micro hydro projects in the country [3, 28]. At present, productive loads such as two flour mills, one saw mill and one poultry firm are energised through this project. However, there still exists potential to create additional productive loads. Since the village economy is largely based on agriculture, productive loads of that nature could possibly be introduced. This needs designing policy thrusts to create productive loads which would not only optimise the plant capacity, but also enable income generation and employment at the local scale. Though specific subsidy schemes are put in place to enhance the end use applications, this has not been the case for every project.

In sum, it was found that the mini-grid project has been running successfully with a low annual average downtime of 9 %. The project has been able to generate positive impacts in terms of bettering the social infrastructure in the village by energising schools, health centres, improving the socio-economic conditions of local people by enhancing income and generating employment opportunities and empowering women through provision of modern lighting systems, thereby reducing their drudgery. The formation of a co-operative in the village to manage the project has also been able to create better social capital in the village. However, there exist a few challenges as far as sustainability of the project is

Table 3 Electricity demand constituents per HHs and scenarios

Items	Poor HH	Middle HH	Rich HH	Commercial load	Productive load
Base case	3 × 12 W lighting load for 5 h (5–10 pm)	3 × 12 W lighting load for 5 h (5–10 pm) and 1 × 80 W TV for 4 h	3 × 12 W lighting load for 5 h (5–10 pm), 1 × 80 W TV for 4 h and 1 × 500 W freezer for 6 h (10 am–4 pm)	420 W lighting and fan load for 5 h, 600 W computer for 1 h and 600 W refrigerator for 15 h	Two flour mills of 5 kW each and one saw mill of 3 kW for 3 h and 1 kW of poultry load for 6 h
S1	3 × 12 W lighting load for 5 h (5–10 pm)	3 × 12 W lighting load for 5 h (5–10 pm) and 1 × 80 W TV for 4 h	3 × 12 W lighting load for 5 h (5–10 pm), 1 × 80 W TV for 4 h and 1 × 500 W freezer for 6 h (10 am–4 pm)	420 W lighting and fan load for 5 h, 600 W computer for 1 h and 600 W refrigerator for 15 h	Two flour mills of 5 kW each and two saw mills of 3 kW each for 3 h and 1 kW poultry load for 6 h
S2	3 × 12 W lighting load for 5 h (5–10 pm)	3 × 12 W lighting load for h (5–10 pm) and 1 × 80 W TV for 4 h	3 × 12 W lighting load for 5 h (5–10 pm), 1 × 80 W TV for 4 h and 1 × 500 W freezer for 6 h (10 am–4 pm)	420 W lighting and fan load for 5 h, 600 W computer for 1 h and 600 W refrigerator for 15 h	One flour mill of 5 kW for 6 h, and one flour mill of 5 kW and two saw mills of 3 kW each for 3 h and 1 kW poultry load for 6 h
S3	3 × 12 W lighting load for 5 h (5–10 pm)	3 × 12 W lighting load for 5 h (5–10 pm) and 1 × 80 W TV for 4 h	3 × 12 W lighting load for 5 h (5–10 pm), 1 × 80 W TV for 4 h and 1 × 500 W freezer for 6 h (10 am–4 pm)	420 W lighting and fan load for 5 h, 600 W computer for 1 h and 600 W refrigerator for 15 h	One flour mill of 5 kW for 6 h, and one flour mill of 5 kW and two saw mills of 3 kW each for 3 h and 1 kW poultry load for 6 h and 5 kW furniture *industry* for 3 h

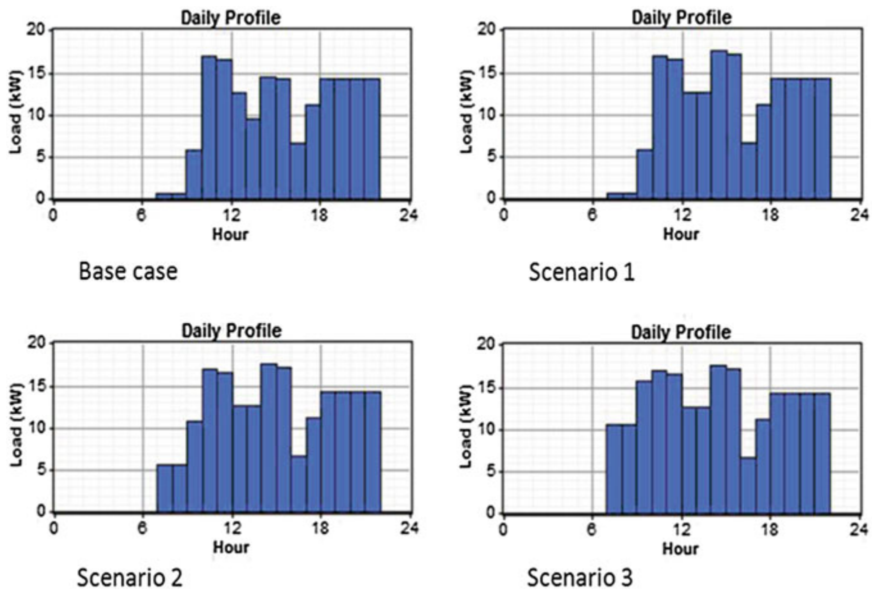

Fig. 5 Load profiles for different scenarios

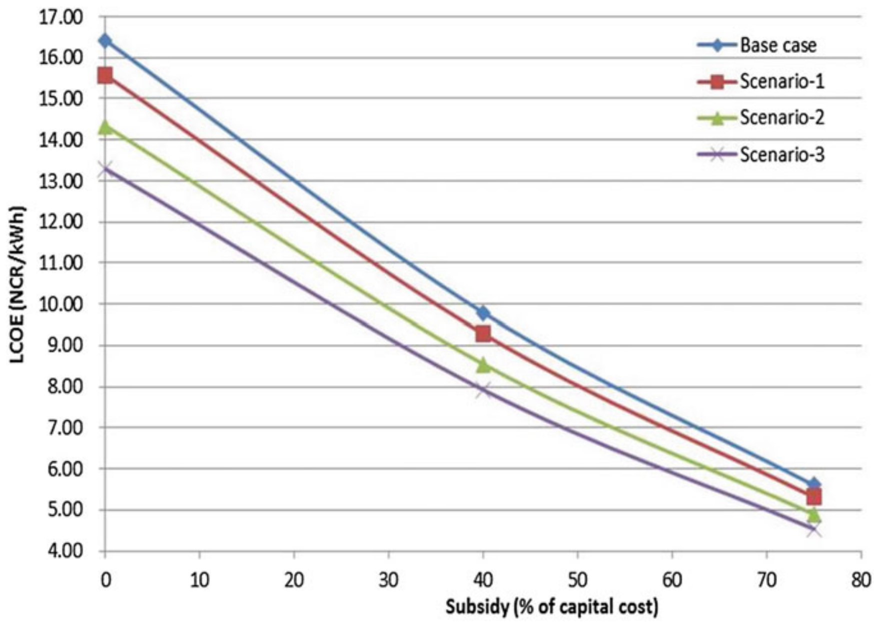

Fig. 6 Subsidy and its impact on LCOE—sensitivity analysis

concerned. Apart from the challenge of low load factor identified above, another related challenge is the lack of technical capacity at the local level to deal with unforeseen technical problems of the project. Additional challenge emerged during the period of project installation. It was difficult for communities to mobilise finance through loans from formal credit institutions due to lack of collateral. The next section discusses in a more detailed manner the generic set of challenges being confronted by the off-grid sector in the country.

8 Barriers to Scale Up

Despite policy thrusts, renewable energy-based mini-grid electrification in Nepal confronts multiple challenges and constraints. There exist multiple economic, social, political and institutional bottlenecks for up-scaling and wider dissemination of renewable energy-based mini-grid electrification projects in the country. The first 3 Year Interim Plan (2007–2010) of Government of Nepal recognised this slow progress of the alternative energy sector in the country and attributed it to the existing economic, social and institutional handicaps.

On the policy front, lack of strong legal framework in terms of an overarching act or policy, absence of clearly spelt out long-term realistic targets and lack of integrated rural development plans retard the growth of renewable energy-based mini-grid electrification process in the country. Most of these targets are ad hoc in nature as spelt out only in the annual budgets of the Government or are set by donor funded programmes. Subsidy policies declared from time to time are argued to have flawed design features thereby leaving scope for manipulation. For instance, subsidy schemes introduced in 1981–1982 resulted in undesirable cost escalation [16]. In overall, subsidy policies in Nepal have not succeeded in delivering the desired outcomes largely due to inherent complexities in the delivery mechanisms [7]. Subsidy mechanisms need to be simpler and should have provisions of gradual phasing out.

The weak institutional structure is characterised by lack of centralised energy planning, duplication of efforts resulting from lack of co-ordination, and disputes between local and national level institutions and cumbersome decision-making processes [16, 28]. Even renewable energy programmes implemented by donor agencies lack co-ordination and harmonisation. Multiple organisations continue to work on alternative energy space and are often having overlapping mandates. Incongruent legal provisions add further woes. For instance, while MHP and SHP systems are de-licensed on one hand, stipulations of Local Self-governance Act 1998, assign power to the local authorities to prioritise the use of water in their jurisdiction, generating potential conflict of interest among different stakeholders. In addition, local level institutions like village/community scale organisations lack managerial capacity to manage micro-hydro systems, thereby pose threat to the sustainability of these projects. This necessitates the need for continuous community mobilisation and capacity building.

Often societal constraints transpire into technical handicaps for the mini-grid projects. Low load factors emanating from low electricity demand have been a major concern for the sector in majority of the cases. It is posited that a majority of community-based micro-hydro projects have a maximum load of 20–25 % [3]. Because of this low load factor, private entrepreneurs do not consider this as a potential business avenue, and generally averse to invest in the sector. There is a need to identify and assess the potential of energy-operated cottage industries in areas where these mini-grids are deployed.

Challenges associated with the financing of mini-grid projects in the country require targeted approach. Access to credit has been found to be the major hindrance for promotion of renewable energy-based rural electrification in the country [23]. Poor access to credit by rural entrepreneurs is largely due to lengthy bureaucratic procedure, lack of collateral and due to associated high transaction costs. In addition, financial institutions providing loans for the renewable energy sector in Nepal suffer from problems of bad debt primarily due to financially weak and vulnerable community structures and loose contractual links between equipment providers and their local agents [8]. Thrust should be laid on carbon financing as an additional source of finance to enhance the financial viability of mini-grids. Though some efforts have been undertaken in this direction, there still exist avenues to mobilise additional financial resources through carbon financing. Transaction costs of administering the financing of small projects are high, thereby deterring banks to venture into small-sized projects. In addition, absence of collateral makes it difficult for the banks to provide loans for these small-scale interventions.

There has also been a host of regulatory hurdles encountered by renewable energy sector in the country. Though, AEPC is placed at the helm of affairs as far as renewable energy sector is concerned, it also plays as a regulator for purposes like quality checking, disbursement of subsidies, and waiving of taxes and duties. Regulatory power of AEPC is limited primarily because of dominance of the nodal Ministry, i.e. Ministry of Science, Technology and Environment (MoSTE). Another regulatory challenge comes in the form of regulatory uncertainty about grid extension thereby stifling the private entrepreneur spirit to venture into the field. Studies point that almost 27 % MHP projects are within the vicinity of 5 km of grid electrification, thereby threatened by the possibility of grid extension in the near future [26]. In addition, monopolised structure of NEA has also been putting additional constraints. NEA is unwilling to connect MHPs with the centralised grid systems largely because of small capacity of the projects and due to technical and managerial constraints arising out of connecting these small projects with the grid. Another major regulatory challenge is associated with the lengthy and difficult project approval process. Approvals in the form of water source use license, company registration and tax registration derail the process of project approval [3]. It emanates from the discussion that though a liberalised environment has been created for the development of micro-hydro projects by delicensing projects up to 1,000 kW [21], it appears that the benefits of this liberalised environment has been translated into practice due to several associated constraints.

Inadequate capacities have also been posing as a threat for the successful growth of the sector. At the macro level, limited testing capacities of renewable energy test station (RETS) is creating sort of a 'technology lock in'. This has been primarily due to lack of adequate funds to equip the centre with advanced testing equipment combined with lack of adequate number of professionals to carry out the test.

9 Policy Recommendations

It emerges from the discussion above that renewable energy-based mini-grid systems have become the prime vehicle of electrification, especially in rural areas of the country. Though some laudable efforts have been undertaken by Government of Nepal through AEPC and by several associated actors and institutions, the sector still requires some specific policy thrusts and focus.

One of the challenges encountered by the sector is the lack of adequate investment, private investment in particular. Declaration of a long-term policy for the sector with necessary incentives and benefits could go a long way in attracting private investors into the field. In addition, sustainability of these projects requires mobilising small-scale financing through micro-financing and micro-credit routes. Another pertinent concern is about policy and regulatory certainty regarding grid extension. Demarcation of off-grid villages/localities by the Government could address policy uncertainties about grid extension, as has been done in Sri Lanka very recently.

Techno-economic comparative assessment of solar energy systems with micro-hydro systems reveals that solar-based systems are relatively expensive compared to hydro-based systems. However, a major concern with small-scale micro-hydro systems is the unutilised and underutilised capacity. Though, subsidy schemes exist for better end use applications, this has not been very successful in creating the required income and employment opportunities to sustain the productive end uses. Therefore, there is a need for better planning and designing from the beginning of the project initiation for the optimal use of energy keeping in consideration the present and future energy requirements of the local people.

Institutionally, the sector requires better co-ordination and harmonisation among various ministries, agencies, and donor agencies and other actors. AEPC by combining the entire donor-funded programmes under one umbrella, i.e. National Rural and Renewable Energy Programme has been able to address this co-ordination problem to some extent. However, there still exist legal entanglements across policies and legislations, which require focused attention.

On the policy front, a long-term credit disbursement path should be declared with phased reduction of subsidies in order to develop sustainable off-grid energy sector in the country. Pockets should be identified, where private entrepreneurs could take lead roles in promoting off-grid energy systems. In addition, in the name of quality control, private entrepreneurs should not be demotivated to introduce better and advanced technologies. Given limited capacity of quality control authorities, quality ranges should be spelt out with flexibility to allow private entrepreneurs to innovate and introduce new technologies.

10 Conclusion

Renewable energy-based mini-grids in Nepal could serve as an effective alternative to the crisis ridden centralised electricity system. Substantial progress in this front has been achieved in the country primarily due to presence of a strong and focused engagement of several key institutions and agencies like AEPC, donor organisations, financial institutions like banks, private associations and, moreover, due to emergence of strong market elements nurtured by private entrepreneurs in the field. Financial evaluation of a micro-hydro mini-grid project reveals there exists room for cost reduction through enhancement of productive uses of energy and creation of livelihood opportunities. Comparative assessment of a micro-hydro project with similar capacity of solar project suggests that micro-hydro projects have cost advantage over solar projects. However, the sector still suffers from several anomalies and imperfections leading to slow progress of the sector. Political instability and uncertainty stand as a major roadblock. Adhocism and changing focus of donor funded programmes are distorting the very foundation of the sector. On the regulatory front, uncertainty about grid extension leads to underutilisation of private sector potential. In addition, poor access to credit and absence of formal financial institutions at the local level debar the ability of private entrepreneurs to venture into the sector. Importantly, lack of post installation evaluation of projects produces only dry statistics on the number of projects deployed without any information about their sustainability. It is pertinent to address all these concerns in a systematic and comprehensive manner to drive the sector on a sustainable trajectory.

Annexure

Table A.1 Key stakeholders interviewed

S. No.	Name	Organisation
1	Mr. Saroj Rai	SNV, Netherlands, Nepal
2	Prof. Govind Raj Pokharel	Alternative Energy Promotion Centre (AEPC), Nepal
3	Mr. Ram Prasad Dhital	Alternative Energy Promotion Centre (AEPC), Nepal
4	Mr. Madhusudhan Adhikari	Alternative Energy Promotion Centre (AEPC), Nepal
5	Mr. Jagadish Kumar Khoju	Alternative Energy Promotion Centre (AEPC), Nepal
6	Mr. Bhupendra Shakya	Renewable Energy for Rural Livelihood Programme (RERL)
7	Mr. Dilli Prasad Ghimire	National Association of Community Electricity Users-Nepal (NACEUN)
8	Prof. Tri Ratna Bajracharya	Centre for Energy Studies (CES), Institute of Engineering, Tribhuvan University, Nepal
9	Dr. Shree Raj Shakya	Centre for Energy Studies (CES), Institute of Engineering, Tribhuvan University, Nepal
10	Mr. Vishwa Bhushan Amatya	Practical Action, Nepal
11	Mr. Vijaya P Singh	UNDP, Nepal
12	Mr. Satish Gautam	Renewable Energy for Rural Livelihood Programme (RERL)
13	Ms. Anupa Rimal Lamichhane	UNDP, Nepal
14	Sanjay Kumar Gokhali	GIZ, Nepal
15	NEA Nepal	
16	Mr. Purna N Ranjitkar	Nepal Micro Hydropower Development Association (NMHDA)
17	Mr. Raj K Thapa	Solar Solutions Private Limited
18	Mr. Prem Bdr. Basnet	Renewable Energy Test Station (RETS), Nepal
19	Mr. Rudra Mani Pokharel	Renewable Energy Test Station (RETS), Nepal
20	Ms. Barsha Shrestha	Clean Energy Development Bank Ltd., Nepal
21	Mr. Nabin Bhujel	Suryodaya Urja Pvt., Ltd.,

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