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Supporting Rural Electrification in Developing Countries

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Nepal

Country profile

Nepal is a country in South Asia with a population of 28.5 million, of which 81% live in rural areas[1]. With the Himalayan mountain range along the northern border with China, Nepal is heavily dependent on its southern neighbour India for key imports such as fuel. Major earthquakes in 2015 caused significant loss of life and damage to infrastructure, the effects of which are still being felt. Transportation and logistics networks are very basic, especially in rural areas, which makes development challenging and decentralisation important.

As of 2016 76% of people have access to electricity[1] which is sourced mainly through the country's abundant water resources. Nepal has an estimated 40 GW of economically exploitable hydropower potential, one of the highest in the world, but so far has developed a total capacity of just 780 MW across all generation sources[2]. Blackouts and load shedding, the practice of denying power to certain areas to guarantee it to others, used to be commonplace in the capital Kathmandu but recent interventions have reduced the use of these measures, although they are still present in rural areas[3]. Approximately four per cent of the country's generation capacity is from off-grid run-of-river hydropower systems supplying rural communities. It is used mainly for basic services such as lighting and phone charging[2]. By 2030 the government aims to have installed 12 GW of hydropower, 2.1 GW of solar and have achieved 99% electricity access[3].

Minigrids in Nepal

How are minigrids used now?

Minigrids in Nepal are supplied almost exclusively by hydropower. Owing to the abundance of available sites, run-of-river systems have been the most popular technology choice and as a result the country has a long history of successful projects and institutional knowledge. A system is sized according to the community's peak demand, typically in use for two to three hours in the morning and three to four hours in the evening. A system is installed with a capacity that should be sufficient to meet this load for at least 11 months of the year. The advantage of this approach is that peak demand will be reliably satisfied. A disadvantage is that the majority of power generated during the day is dumped and goes unused, resulting in a low load factor. Few communities use systems powered by solar or wind generation, whose decreasing costs could provide affordable, reliable and low-maintenance electricity. However, the Government of Nepal's Alternative Energy Promotion Centre (AEPC) has activities in assessing their feasibility via case studies and a small number of developers are currently operating.

The majority of minigrid systems are owned, at least in part, by the communities they serve. These cooperatives are normally overseen by a village energy committee, which allows the assigning of responsibility for the operation of the system and for payment collection. This management system has been successful in ensuring the longevity of the system and minimising payment defaults, but limits development as it provides little incentive to expand a system's capabilities and therefore the level of energy access of the community.

What support mechanisms are in place?

AEPC are responsible for providing technical evaluations and assessing the government subsidy amount for minigrid projects. The subsidy is calculated on the basis of either the number of households served, the actual generation capacity or the actual energy consumption from the system. Typically an off-grid system will receive around 40% of the project cost covered by this subsidy, 30% from the community and 30% from loans and commercial financing, but far higher subsidies are available under certain circumstances[4]. Subsidy mechanisms have been designed to be technology agnostic for off-grid electrification to encourage the most cost-effective options. Approximately US$310 per household is awarded in the most remote regions for hydropower, solar, wind, biomass and hybrid systems, or US$270 for more accessible regions[4]. Capacity-based subsidies vary depending on the technology chosen, which could lead to favouritism, although limits are placed on the total subsidy amount received by a single project.

This subsidy structure has been effective at encouraging rural electrification but has not been without issues. A high reliance on generous subsidies has fostered a dependency that has hampered the progress of private sector investment, and the timescales for approval of manufacturers, developers and contractors has limited competition and improvements in quality. Systems are regularly constructed at a higher capacity than necessary to take fullest advantage of the subsidy available. This improves the performance of a given system but it is not an efficient use of resources overall. In the past, subsidies have been aimed at providing basic energy access and the systems have been designed accordingly, but no subsidy mechanisms exist to increase capacity or retrofit systems to make them appropriate for increased electricity use as the village economy develops, for example through an improved matching of supply and demand.

What are the challenges and opportunities?

There is significant interest amongst many different stakeholders about increasing the electricity use in communities. If productive and income-generating activities could be established using the current oversupply from micro-hydro systems, for example via agro-processing or handicraft manufacturing, the economy of the community could be developed and the load factor of the system could be increased. Future hydropower systems should be designed with greater balance between meeting high loads and optimising energy usage throughout the day, for example using a reservoir to store water for greater generation during the evening peak.

In comparison to other countries there is little development of different minigrid business models in Nepal. Most systems are owned and operated by their communities and there is therefore little activity for commercial micro-utilities selling energy as a service, which limits incentives for development. Companies that offer this service could open up a large market in villages without existing minigrid systems, especially as grid extension – often a threat to the business models of micro-utilities – is less likely here than in other countries owing to the unique and challenging geography of Nepal.

Directions for future research

The dominance of hydropower minigrids means that solar and wind generation are lagging significantly in comparison to other countries around the world. Suitable technological solutions exist but have not yet been implemented. This inertia is exacerbated by the regulations surrounding subsidies, although the challenge is being addressed by AEPC feasibility studies. Decreasing the regulatory requirements could help foster the growth of private companies using a more diverse range of technologies, but carries a greater risk if they were to fail.

The need for battery storage is seen as a key barrier to renewables deployment: battery lifetimes are considered to be lower in the high altitude climate of Nepal and the cost of their replacement is incompatible with current subsidy schemes. Research into the performance of battery technologies in Nepal, especially the emerging presence of lithium ion batteries, would allow more informed decisions by both policymakers and developers about the most appropriate minigrid systems to deploy.

With the costs of solar, wind and battery technology decreasing, renewables are already cost competitive with diesel generation and would likely be the better option in places without adequate hydropower potential, especially the most remote areas. The relatively low maintenance requirements of solar, for example, make it an attractive option for anchor loads in remote areas such as telecoms towers, a strategy used in many other countries.

Hybrid systems of two or more technologies are being used at some sites but their benefits are not being fully exploited. Existing hydropower systems could store excess generation by using batteries to meet peak demand, reducing their total generation capacity requirements, or combined with solar or diesel generation to meet peak demands. Alternatively water could be stored during the day, during which time power is provided by solar. Hybrid systems would also increase the resilience of rural communities to natural disasters. After the earthquakes in 2015 many hydropower systems were offline for months or more owing to damage and lack of spare components; solar could have provided a backup to ensure at least some electricity supply during that period.

Rwanda

Country profile

Rwanda is a small landlocked country in East Africa with a population of 11.6 million[7], of which 71% live in rural areas. It has the highest population density in Africa. Politically stable since 1994, the Government of Rwanda is renowned for ambitious targets for social and economic development. It achieved a real GDP growth averaged at 8% per annum in the period 2001-2015[7]. In 2000, the Government of Rwanda published 'Vision 2020', a programme that outlines Rwanda's long-term development plan to become a middle-income country with a knowledge-based, service-oriented economy. To achieve this goal, investment from the private sector must be encouraged, however progress to date has been constrained by poor infrastructure and access to electricity.

As of 2016, 18% of the population have access to electricity, up from six per cent in 2008[8]. Rwanda's energy sector target is for 70% of households to have access to electricity by 2018, established in the Energy Sector Strategic Plan and the National Energy Policy. In the Ministry of Infrastructure's (MINIFRA) recent Rural Electrification Strategy, this increases to 100% by 2020, with total power generating capacity increasing from 160 MW in 2015 to 563 MW[9,10]. Until recently Rwanda has suffered from supply shortages and severe load shedding, where power is denied to some areas in order to guarantee power to other areas. The majority of generation capacity in 2015 was comprised of hydropower (57%) and diesel (37%). The strain on the power system has been made worse by the impact of regional drought on hydropower supply. The high import cost of diesel and rental of generators means that tariffs are high, up to US$0.22/kWh compared to US$0.12/kWh in neighbouring countries, in addition to high connection fees.

Rapid economic development and urbanisation means power demand in Rwanda is set to grow. If the government wants to reduce the average cost of energy whilst delivering their energy targets, domestic resources and off-grid solutions will be vital. Rwanda has an estimated 313 MW of hydropower potential (including over 12 MW off-grid potential), 500 MW of geothermal energy, 350 MW from methane reserves, 300 MW from peat reserves and a moderate solar potential of four to six kWh per square metre per day.

Minigrids in Rwanda

How are minigrids used now?

Minigrids in Rwanda are owned and operated by private micro-utility companies. An advantage of continued private ownership of the installed system is the incentive for the company to maintain a good service and expand capability and access where possible. The deployment of minigrids to date is limited. Solar home systems are more widespread partly due to the flexibility of acquiring customers one at a time. Connecting a community with a minigrid requires a higher upfront cost so a threshold of initial customers is required to make it worthwhile. While a handful of private companies are in the process of deploying minigrids, few companies have already installed them. Existing systems are usually centred on solar power, with a modular approach allowing their expansion if demand grows. This design reduces the initial capital costs and gives the company flexibility to redeploy should the grid arrive. Lead acid batteries are used as storage almost exclusively, owing to their low cost and the ability to recycle them locally. The typical size of communities connected to a minigrid system is 50-100 households, receiving basic energy services for lighting, phone charging and radios. To increase profitability the micro-utility must encourage growth in customer demand, for example by increasing the number of connections or larger applications such as TVs, fans and refrigeration. This is proving difficult, however, owing to the low and seasonally varying income of their customers, which limits their ability to make reliable payments for the services.

Support Mechanisms and Subsidies

The Government of Rwanda recognises the need to support private companies working in the rural electrification sector, to encourage investment and minimise risk, if it is to meet the targets set out in 'Vision 2020'. The most recent rural electrification strategy, published by MININFRA in June 2016, puts the private sector in the lead in financing and delivering off-grid energy access. Government financial support will focus on:

- enabling the basic level of electricity to those with the lowest income;
- risk mitigation for the private sector in providing rural electrification systems, for example location advice based on grid extension plans;
- supplying educational and promotional goods support in the supply chain; and
- establishing a framework in which to operate.

Initial funding from the Government and development partners will be available to help establish an attractive market for further private investment in the future.

Ultimately, the majority of financial support available for minigrid operators comes from foreign aid, either directly or via the Government.

The Scaling-up Renewable Energy Program, part of the Climate Investment Funds, has approved US$ 50 million of donor capital for the Rwanda Investment Plan to reduce barriers and accelerate growth in off-grid electricity access, including the use of minigrids. A further US$ 49 million, close to approval, will set up a Renewable Energy Fund with the aim of catalysing private sector investments in renewable energy technologies, including minigrids[13].

Challenges and opportunities

It is challenging for minigrid micro-utilities in Rwanda to make their commercial venture sustainable and financially successful. The success of a micro-utility minigrid relies on having a high number of paying customers. A common practice is to offer a low-cost basic package (usually lighting services only) to achieve the initial connection threshold in a community, with the aim to later upsell customers to higher load packages (phone charging, radio and TVs), or encouraging others in the community to join. To date, further connections and graduation from the basic packages remains low, the main barrier being the low and seasonally varying household income in rural communities. Even companies providing stand-alone home systems, which do not require several customers within a single community, are struggling to encourage customer power progression, leading to oversized home systems. To overcome this challenge, community income should be increased through the encouragement of local enterprise and productive end uses, examples of which could be agro-processing, SMEs or even community refrigeration. While such uses will improve the load factor of the system, which benefits the operator, it also provides a societal benefit by stimulating further socio-economic opportunities for the connected community.

The widespread use and availability of mobile payment in Africa is one of the major facilitators allowing micro-utilities to operate a power usage-based business model with streamlined payment collection. To manage energy usage, systems need to be 'smart' so they can be monitored and remotely controlled with the potential for remote switch-off if the customer defaults on payment. This real-time feedback means that companies are collecting vast amounts of data on the system performance and customer usage, as well as social and financial data, providing knowledge about a previously unknown customer market. This information allows companies to continually improve system efficiency and informs their business strategy.

Directions for future research

Rwanda is a small country with ambitious grid extension plans. As a result, the arrival of the grid in communities currently served by minigrids is a significant risk for micro-utility companies operating the minigrids. While the presence of the grid should be preferable in theory, high connection fees may mean customers are unable to pay and are left without access to electricity if the minigrid company is forced out by the arrival of the grid. Government plans, advice and promises on grid extension can mitigate this, however the option of hybrid minigrids interfacing with the national grid may offer better long-term security for micro-utilities and should be investigated.

Solar is, to date, the most widely used technology for off-grid electrification in Rwanda and the feasibility of alternative off-grid technologies such as wind or hydropower, especially as part of hybrid minigrid systems, remains largely unstudied. Any benefits that hybrid systems could bring would need to be compared to the additional costs they would incur, and should be investigated through feasibility projects. The cost associated with battery storage and replacement could be reduced if complementary generation sources were available and multiple sources could be integrated into a hybrid minigrid.

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