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Supporting Rural Electrification in Developing Countries

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Case Study: Utilising Hydropower in Nepal

Introduction

Hydropower is by far the most common generation choice for minigrids for rural electrification in Nepal. This has proved successful in providing power to remote communities but is not without issues. Hydropower plants are often built bigger than necessary to gain the maximum amount of subsidies, but this can promote an inefficient use of resources. These systems ensure that demand is met consistently in peak evening periods, which last a few hours, but cause very low load factors as power generated during the daytime goes unused. Finally, once a hydropower system is installed, it can constrain the ability to install additional hydropower generation in the same location, which causes issues if the capacity becomes inadequate through a growth in electricity demand. Here we have used CLOVER to assess an example installed hydropower system in meeting the domestic loads it was designed for, the effect of including productive demand to increase load factor, and different options for increasing electricity consumption to provide reliable power to the community.

In this case study we consider an example based on a minigrid in a village in the hilly Baglung District of Western Nepal. This community of 165 households has access to a 9 kW hydropower plant to meet their electricity needs for domestic services, phone charging and entertainment, and also for productive income-generating activities. We assume that households have access to an average of three lights and own two phones that require charging twice per week. Approximately one in ten households own a television and one in three own a radio powered from the minigrid system. Within the community there is a demand for electricity for productive purposes: three agro-processing mills (five horsepower each), six workshops with electrical tools and five small enterprises, for example tailors or handicraft artisans.

Analysis of the existing hydropower plant

An assessment using CLOVER of the present nine kW hydropower plant reveals that it would be sufficient to meet all domestic demand throughout the day but with a low load factor of 24.6%. When commercial loads are included the increase in daytime demand successfully increases the load factor to 60.1%, albeit at a cost. For an average of two hours 45 minutes per day, the electricity supplied by the system is insufficient to meet both domestic and commercial demand and blackouts occur between 16.00 and 21.00 when the two demands occur simultaneously. This shortfall limits the usefulness of the system for domestic purposes and increases the reliance upon kerosene, and disrupts productive uses, potentially limiting economic growth.

Assessing additional generation capacity

The existing system can be upgraded to provide reliable power for domestic and productive purposes either by additional renewable or fossil fuel generation, or a combination of the two. By analysing the shortfalls in demand from existing hydropower system, CLOVER has provided three optimised options for electricity generation with an average of less than 15 minutes of blackouts per day over a five-year period. Table 1 displays the additional capacity requirements, their costs and GHG emissions, and efficacy at meeting the total community demand.

The renewable option is the most expensive but provides low GHG emissions and a favourable degree of autonomy. Although battery costs contribute significantly, they are unlikely to need to be completely replaced after the considered five-year period as they are used only moderately, although more research is needed into the long-term performance of batteries in Nepal. Diesel power provides the opposite: lower costs, but higher GHG emissions and a reliance on consistent fuel delivery that may be unfeasible for a remote community. Furthermore the fuel costs after the five-year period will continue to be high and susceptible to fluctuations in diesel price.

A hybrid of hydropower, solar and diesel can return a conservative multi-generation option at both low cost and low GHGs. The hydropower and solar components both experience high utilisation, and the diesel generator allows the flexibility of power to be dispatched when necessary. Even if diesel generation becomes completely unavailable, for example when fuel is unobtainable, the system will continue to provide power 94% of the time. This hybrid option provides the most appropriate and resilient choice for satisfying the domestic and productive loads in this village.

System analysis using CLOVER

An analysis by CLOVER of the hybrid energy system is shown in Figure 1. On the left, commercial loads (green) provide a significant increase to the capacity factor of the system during the daytime, but when combined with domestic loads (red) in the evening the total load (purple) becomes greater than the supply from hydropower (blue). On the right, generation from solar (yellow) matches the times of commercial demand well and provides energy during the daytime to augment the hydropower capacity, whilst diesel power (grey) delivers electricity during the evening peak to ensure reliability. The data shown is the hourly average over the considered five-year period, however seasonal and daily fluctuations will vary the generation and load demands significantly; these are included in the modelling assessments.

CLOVER has been used to model, assess and analyse various options for delivering power to the remote community in Baglung District and provided a suitable system design to meet domestic and commercial loads reliably and affordably.

	Capacity	Cost [i] ($ 000s)	Energy generated (MWh/year)	Energy consumed (MWh/year)	Load factor (%)	GHG emissions (tonneCO2)
Current system						
Hydro	9 kW	–	80.0	19.7	24.6	–
Renewable						–
Hydro	9 kW	–	80.0	50.4	53.6	–
Solar	8 kWp	8.0	14.0			26.6
Batteries	61 kWh	18.3	–	4.6	–	6.6
Total		**26.3**	**94.0**	**55.0**	**58.5**	**33.2**
Diesel						
Hydro	9 kW	–	80.0	48.1	60.1	–
Diesel	26 kW	11.8 + 9.4 [ii]	10.6	10.6	46.7 [iii]	60.0 [iii]
Total		**21.2**	**90.6**	**58.1**	**64.1**	**60.0**
Hybrid						
Hydro	9 kW	–	80.0	50.2	53.4	–
Solar	8 kWp	8.0	14.0			6.6
Diesel	26 kW	11.8 + 3.2 [ii]	6.0	6.0	49.0 [iii]	32.4 [iii]
Total		**23.0**	**100.0**	**56.2**	**56.2**	**39.0**

Table 1: Assessment of options to upgrade the existing hydropower system to ensure reliability for all loads in comparison with the present day hydropower system for domestic loads only.

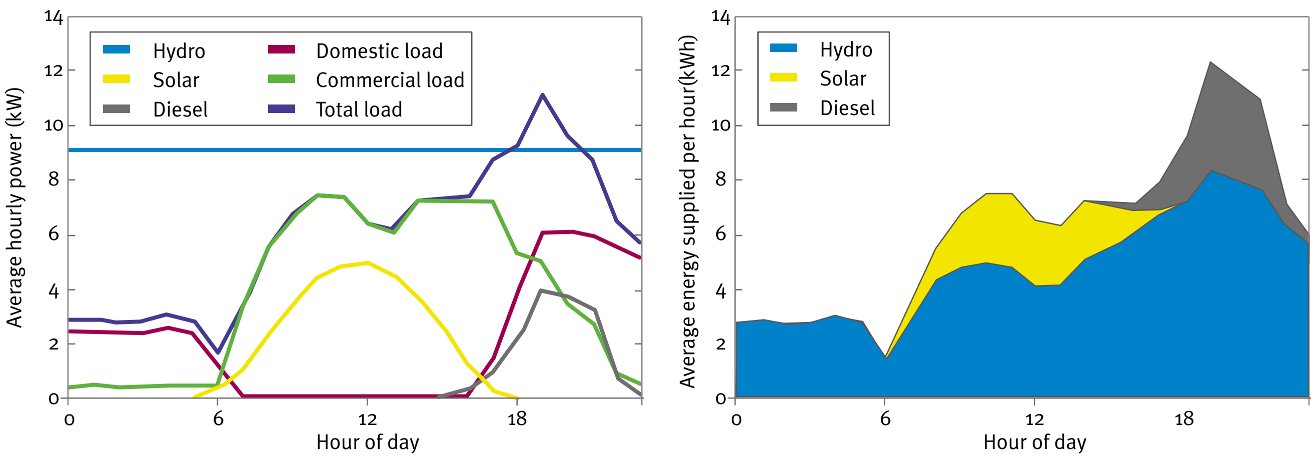

Figure 1: Average power generated and load demanded by hour (left) and average energy supplied by each source (right), the sum of which is the total hourly electricity demand and system losses.

i Representative costs associated with the additional generation capacity installed, not including those from the distribution lines, metering systems or other infrastructure which is assumed to already exist as part of the initial hydropower minigrid system.
iii Cost of equipment and fuel for the five-year period.
iii During usage of diesel generator.