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Nepal: Scaling Up Electricity Access through

Mini and Micro Hydropower Applications

A strategic stock-taking and developing a future roadmap

WORLD BANK GROUP

ASTAE

Asia Sustainable and Alternative Energy Program

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Contents

ANNEXES

LIST OF FIGURES

LIST OF TABLES

LIST OF BOXES

Abbreviations and Acronyms

ACAP	Annapurna Conservation Area Project
ADB	Asian Development Bank
ADBL	Agriculture Development Bank Limited
AEPC	Alternative Energy Promotion Centre
AVR	automatic voltage regulator
BEP	break-even point
capex	capital expenditure
CBRE	community based rural electrification
CDM	clean development mechanism
CDM-PDD	clean development mechanism-project design document
CEB	Ceylon Electricity Board
CER	certified emission reduction
CFL	compact fluorescent lamp
COs	community organizations
CoD	cost of distribution
CoG	cost of generation
CREF	Central Renewable Energy Fund
DANIDA	Danish International Development Agency
DC	direct current
DDCs	district development committees
DEECCS	District Environment, Energy and Climate Change Section
DEES	District Energy and Environment Section
DFID	Department for International Development
DFS	detailed feasibility study
DoED	Department of Electricity Development
DWRC	District Water Resources Committee
EDC	Electricity Development Center
EIRR	economic internal rate of return
ELC	electronic load controller
ESAP	Energy Sector Assistance Program
EU	European Union
EUR	Euro
FIRR	financial internal rate of return
FIT	feed-in-tariff
FM	frequency modulation
GEF	Global Environment Facility
GIS	Geographic Information System
GIZ	German Society for International Cooperation
GoN	Government of Nepal
HH	households
HT	high tension

ICT	information and communications technology
IDA	International Development Association
IEEE	Institute of Electrical and Electronics Engineers
IFC	International Finance Corporation
INGO	International non-governmental organization
INPS	Integrated Nepal Power System
IPP	independent power producers
IRR	internal rate of return
ITDG	Intermediate Technology Development Group
KfW	Reconstruction Credit Institute (German Development Bank)
kLh	kilo-lumen-hours
kVA	kilo-Volt-Ampere
kW	kilo-Watt
kWh	kilo-Watt-hour
l/s	liters per second
LDC	load dispatch center
LEUA	Lamjung Electricity Users' Association
LPO	local partner organizations
LUBE	levelized unit benefit of electricity
LUCE	levelized unit cost of electricity
m	meter
MHFG	micro hydro functional group
MHP	mini and micro hydropower plants
MHVEP	Micro-Hydro Village Electrification Programme
MoEn	Ministry of Energy
MoSTE	Ministry of Science, Technology and Environment
MoWR	Ministry of Water Resources
MRET	Mandatory Renewable Energy Target
MW	mega-Watt
NEA	Nepal Electricity Authority
NGO	non-governmental organization
NMHDA	Nepal Micro Hydropower Development Association
NMoFA	Norwegian Ministry of Foreign Affairs
NPR	Nepalese Rupees
NPV	net present value
NRREP	National Rural and Renewable Energy Programme
NSP	national service provider
NTNC	National Trust for Nature Conservation
NVMHP	Nepal Village Micro Hydro Program
O&M	operation and maintenance
PAT	pump as turbine
PDD	project design document
PEU	Productive Energy Uses
PLF	plant load factor
POT	power output test
POV	power output verification
PPA	power purchase agreement
PPP	public–private partnership
QA	quality assurance
RCEMH	Regional Centre for Excellence in Micro Hydro
RE	renewable energy

REC	renewable energy certificates
REDP	Rural Energy Development Programme
RERL	Renewable Energy for Rural Livelihood
RET	renewable energy technology
RoE	return on equity
RoI	return on investment
RSC	regional service centers
SAARC	South Asian Association for Regional Cooperation
SARI Energy	South Asia Regional Initiative for Energy
SCADA	Supervisory Control and Data Acquisition
SHP	small hydropower plant
SLREC	South Lalitpur Rural Electric Co-operative Ltd.
SNA	state nodal agency
SNV	Netherlands Development Organization
SPV	solar photovoltaic
TA	technical assistance
TCO_2	ton carbon dioxide
TCO_2eq	ton carbon dioxide equivalent
ToR	terms of reference
TRC	Technical Review Committee
UNDP	United Nations Development Project
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
US$	United States Dollar
USAID	United States Agency for International Development
VAT	value added tax
VDCs	village development committees
VESP	Village Energy Security Programme
W	Watts
WB	The World Bank
WEC	Water and Energy Commission
WECS	Water and Energy Commission Secretariat

CONVERSIONS

Units of measurement

kV = 1000 Volts
kW = 1000 Watts
MW = 1000 kW
GW = 1000 MW

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US$1 = NPR 96
NPR 1 = US$0.0104

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Executive Summary

A. BACKGROUND

1. In spite of the techno-economic potential to generate 43,000 MW of hydroelectric power, Nepal is currently facing a crippling energy crisis. In the fiscal year of 2013/14, Nepal's domestic generation met only 60 percent[1] of the energy demand of grid-connected consumers. Import from India comprised 18 percent of the total energy supplied. Nearly, 22 percent of the demand could not be supplied, leading to load shedding in the grid for up to 12 hours per day. Moreover, around 33 percent[2] of the country's population, mostly in rural and remote areas, does not have any access to grid or off-grid electricity.

2. Shortage of energy negatively impacts economic development by suppressing agricultural productivity, environmental sustainability, health care, education and job creation. This specifically affects poor and rural households as they spend a large part of their income and time fulfilling their basic energy needs.[3] Households that spend 10 percent to 30 percent[4] of their income on energy expenses are considered "energy poor". According to this classification, 80 percent[5] of Nepalese households are energy poor.

3. Development of renewable energy technologies (RETs), both on-grid and off-grid, has become crucial to increase energy access (including electricity) for better overall development, poverty reduction and shared prosperity. Isolated RETs such as micro hydropower, solar photovoltaic (SPV) and biogas can substantially improve the rural economy. Specifically, micro hydropower plants (MHPs) have been serving off-grid rural households in the hilly regions since they were introduced in Nepal in the 1960s.

4. The Alternative Energy Promotion Center (AEPC) was established in 1996 as a central body of the GoN to promote alternative energy, especially in rural areas. Due to efforts by the Government of Nepal (GoN) and development partners since the 5th development plan (1975–1980), rural electricity access through MHPs and the number of stakeholders in this sector have been steadily increasing. With support from the AEPC, more than 25 MW of micro/mini hydropower schemes have been providing off-grid electricity to more than 400,000 rural households.[6] Table 1 presents an overview of the current micro hydropower scenario in Nepal.

5. Significant achievements in the micro hydropower sector have also brought about various challenges that require new approaches. One such major challenge is to address the MHP–national grid interface. As the state-owned electricity utility, Nepal Electricity Authority (NEA), extends its grid to rural areas, many MHPs become redundant if they cannot be grid-connected. According to a preliminary estimate by the AEPC, 90 MHPs[7] with net capacity of 2.7 MW have been affected by the grid extension and this number is steadily increasing. The GoN continues to support isolated MHPs in areas where the grid is unlikely to be extended within a five-year time-period. However, since the NEA does grid extension planning on a yearly basis while the MHPs

1 "A Year in Review – Fiscal Year 2013/14", NEA.
2 National Planning Commission (2014).
3 UNDP (2005).
4 "Measuring Energy Access: Supporting a Global Target", The Earth Institute, Columbia University, USA (2010).
5 AEPC (2012).
6 "Assessment of Nepal Small Scale Rural Energy Market: Supply Side Assessment", IFC (2014).
7 Based on data received by the AEPC from its outreach offices (2013)

TABLE 1 | Overview of the current micro hydropower scenario in Nepal

	Total	Grid encroached	Grid connected	Mini-grid
Number	1,400	90	None*	1
Capacity (kW)	25,000	2,700	NA	107
Number of HHs	400,000	27,000	NA	1,300

** 24 kW Gottikhel MHP was grid connected as a pilot project. This MHP is now disconnected from the grid due to no feed-in tariff agreement between the NEA and the local community (refer to Annex 2 for the details); HHs = households.*

are built to have an economic life of minimum 15 years, it is hard to predict how grid extension will affect MHPs in the long term. This issue is further compounded because the GoN does not formulate a separate rural electrification master plan.

6. If the right policies for connecting MHPs to the grid are not in place, these plants will be forced to shut down and then abandoned. From a national perspective, shutting down such plants before their economic life is over is a waste of resources, especially as implementation of such MHPs has been subsidized and because significant investments have been made by the communities. On the other hand, if these MHPs are allowed to be grid-connected, the resources that have already been invested in building and operating these plants will continue to be utilized. Thus, scaling up and bolstering partnerships on grid-based approaches requires new perspectives by the GoN.

B. OBJECTIVES AND SCOPE OF THE TECHNICAL ASSISTANCE

7. This study has been commissioned to understand barriers and opportunities for scaling up micro hydropower projects and to provide recommendations on how such scaling up can be achieved. In this context, this study conducts analyses on issues pertaining to the micro hydropower sector, provides policy and operational recommendations to the GoN and proposes guidelines for the World Bank's future strategy regarding scaling up of the micro hydropower sector.

8. The broad objectives of this technical assistance are:

- Investigate the performance and sustainability aspects of off-grid mini/micro hydropower plants based on lessons learnt from ongoing projects and from local and international best practices.
- Investigate the technical, financial, regulatory, economic and socio-environmental considerations, as well as barriers and opportunities for scaling up micro hydropower energy access by establishing mini-grids and for integrating such mini-grids to the national grid as per GoN's vision and prospective plans.
- Identify gaps and suggest improvements in the AEPC and NEA's institutional and technical capacity for scaling up micro hydropower access, including ensuring available high-quality standards, good regulatory environment and quality assurance mechanisms.
- Provide strategic and innovative recommendations for scaling up micro hydropower access in a sustainable manner.

C. STUDY METHODOLOGY

9. This study used a rigorous approach and methodology, which included quantitative, qualitative, consultative and field-verification processes with emphasis on economic aspects. Preparation of a roadmap for up-scaling MHPs was based on analyses from regulatory/policy, institutional, technical, financial and community perspectives.

10. AEPC's approach in promoting isolated and grid-connected MHPs and implications of recent technical innovations in distributed generation management were analyzed. International best practices in the context of grid connection of MHPs were reviewed. The current financial status, operational processes, flow of resources, and the project cycles of micro hydropower companies (surveyors,

manufacturers and installers) were reviewed to identify current barriers and recommend measures for financial efficiency. The prevalent managerial approaches, business models and management solutions were studied. Micro hydropower related services provided by regional service centers (RSCs) and local partner organizations (LPOs) under the National Rural and Renewable Energy Programme (NRREP) were reviewed.

11. Two workshops, one at the inception phase and another after completion of the draft report, were conducted to incorporate the views of various stakeholders and organizations involved in the micro hydropower sector such as AEPC, NEA, Nepal Micro Hydropower Development Association (NMHDA), non-governmental organizations (NGOs), international NGOs (INGOs), surveyors, manufacturers and installers.

D. FINDINGS AND RECOMMENDATIONS

12. The findings and recommendations are summarized in this section. Table 2 lists the findings of the economic and financial analyses conducted in Chapter 3.

D.1 STANDALONE MHP

13. The institutional architecture to implement standalone MHPs is very robust and well tested. The micro hydro functional group (MHFG) as an institution is performing satisfactorily and represents the community well. AEPC's community mobilization and empowerment model is quite successful. Over the years, the average MHP size has increased steadily from 17 kW in 2002 to 30 kW in 2013. On the other hand, potential MHP sites are becoming more remote due to which capital cost per kW is increasing. As can be seen in Table 2, rural electrification through MHPs returns three times more economic benefits (i.e. levelized unit benefit of electricity (LUBE)/ levelized unit cost of electricity (LUCE) = 66/22 = 3) than the investment and operating costs. Electricity from SPV or diesel-based local grids is more than twice as expensive as providing the same capacity and level of service through MHPs (by comparing LUCE (e) for diesel, solar, and micro hydropower). Therefore, standalone MHPs must be scaled up as they provide significant economic benefits and are the least-cost RET option. Additionally, government subsidy for MHPs must be continued to deliver high economic benefits as MHPs were found to be operationally viable social enterprises.

14. Typically, the community mobilizes 50 percent of the total project cost to set up an MHP and the balance is provided through the AEPC as subsidy. Mobilization of funds from the community to achieve financial closure is a major bottleneck in micro hy-

TABLE 2 | Summary of findings of financial and economic analyses

Installed Capacity:		20 kW		50 kW		100 kW	
Type of energy source	Parameter	Without Subsidy	With Subsidy	Without Subsidy	With Subsidy	Without Subsidy	With Subsidy
		In Nepalese Rupees* per kilowatt hour (NPR/kWh)					
Standalone MHP	LUCE (f)	73	39	64	36	59	33
	Consumer Tariff (f)	-	6–8	-	6–8	-	6–8
	LUCE (e)	22	-	23	-	24	-
	LUBE (e)	66	-	67	-	68	-
Diesel	LUCE (e)	60	-	-	-	-	-
Solar	LUCE (e)	55	-	-	-	-	-
MHP grid connection	LUCE (f)	18–31	-	12–18	-	11–13	-
NEA's cost of delivery	LUCE (f)	17–25	-	17–25	-	17–25	-

*NPR 1 = US$0.0104

Notes: LUCE or levelized unit cost of electricity is the ratio of discounted operating cost plus capital expenditure to discounted number of kWh generated over the life time of an MHP; LUBE or levelized unit benefit of electricity is the ratio of discounted economic benefits to discounted number of kWh generated over the life time of an MHP; (f) = Financial; (e) = Economic.

dropower implementation. Standalone MHPs are not profitable with or without subsidy when analyzed from a conventional financial viewpoint because of very low plant load factor (PLF) and tariffs that are designed to solely recover funds for salaries and routine repair and maintenance. The LUCE for standalone MHPs is much higher than the consumer tariff being charged. As can be seen from Table 2, the consumer tariff that is being charged by an MHP is NPR 6.00–8.00 per kWh, whereas LUCE (f) is in the range of NPR 33.00–39.00 per kWh. Even when larger MHPs make modest profits operationally, they have no savings to afford major repairs. Therefore, the AEPC should educate bank and financial institutions (BFIs) on the operational sustainability of MHFGs and help reduce interest costs for MHFGs by providing low interest loans in collaboration with BFIs. By increasing the loan amounts, MHFGs will be compelled to increase consumer tariff to repay the loans and the accrued interest, thus strengthening their capacity in tariff setting.

15. Most micro hydropower households are not metered and the extensive use of power-based tariff is discouraging energy conservation. The distribution networks of most MHPs are not up to NEA standards, which hinders grid compatibility. Given that the grid will soon reach most MHP sites in the mid-hills of Nepal, the AEPC should ensure that all MHPs are built 'grid compatible' and NEA standard metering should be made mandatory in all MHPs to promote energy efficiency. AEPC's micro hydropower program is demand driven with the village development committee (VDC) and Ward making up planning unit. This is resulting in the development of several small MHPs in the same area serving adjacent communities, which is leading to under-utilization of the hydropower potential of the site. Therefore, preference must be given to building a larger micro or mini hydropower plant serving more communities rather than building smaller plants serving individual communities.

16. Experienced MHP workers and manufacturers are leaving the industry and moving towards the more profitable larger hydropower sector. New manufacturers and installers who are entering the industry are undercutting costs by compromising on quality of manufactured components and execution of civil works. Therefore, the pre-qualification process of service providers should be revised using a more systematic quality assurance and post-installation survey to monitor and rank performance over an extended period of time. Furthermore, cost benchmarks should be updated taking into account current market prices and efforts should be made to standardize MHP components for cost reduction. The remoteness of MHPs from manufacturers and installers who also provide after-sales services often leads to prolonged downtimes and high costs of repairs. Moreover, there are only nine RSCs, each covering several districts to promote not only MHPs, but also the entire range of RETs that the AEPC supports. Therefore, the AEPC must devolve decision making by establishing regional offices and increasing the number of RSCs and their technical capacity in order to provide supervision of the project.

D.2 MINI-GRID

17. A mini-grid can serve large loads only during the off-peak hours because high surplus power during peak hours is very unlikely as a result of overloading of MHPs during this period. Therefore, financial viability of mini-grids through an increase in the PLF is heavily dependent on greater utilization of off-peak power. Analysis shows that even the optimistic scenario of the PLF doubling after the formation of the mini-grid would not make it viable. Moreover, mini-grids are not financially attractive since the cost of interconnecting MHPs is very high regardless of their capacities. The viability of mini-grids is site-specific and depends on factors such as distance between individual MHPs, market for off-peak power, existing infrastructure such as roads, and the purchasing capacity of the communities. Moreover, when a community initiates a single MHP that is later interconnected to other MHPs to form a mini-grid, problems in terms of identity and ownership may arise as the mini-grid will span over several Wards or VDCs. Therefore, it would be more effective to deliver power to a larger set of consumers from a single larger micro or mini hydropower plant rather than putting up several smaller MHPs and trying to interconnect them later to form a mini-grid. Furthermore, mini-grids have become less relevant

after the NEA removed the 100 kW threshold for grid connection.

D.3 GRID CONNECTION

18. The financial performance of a grid-connected MHP is attractive as demonstrated by incremental analysis based on grid connection costs disregarding earlier MHP implementation costs as sunk costs. Economic benefits of selling surplus power to the grid are also overwhelmingly high. However, such financial and economic benefits are contingent on grid availability. Therefore, the NEA must ensure availability of grid for power evacuation or give deemed generation[8] status to grid-connected MHPs. Furthermore, MHFGs need to be legally registered entities to enter into power purchase agreement (PPA) with the NEA for grid connection. Therefore, the AEPC and RSC need to pilot and formulate the processes required for nurturing and transitioning the MHFG into a formal business organization prior to scaling up. On the other hand, while MHFGs transition into business like ventures, it is important that they retain the principle of community owned and managed assets. The AEPC should also build the capacity of the RSCs and through them of the community to understand the methodology of incremental and total financial analysis presented in this study as a preparatory step to grid connection.

19. Financial analysis shows that delivering electricity through an MHP is cheaper than delivering electricity through NEA's grid. As seen in Table 2, for every unit of electrical energy purchased by the NEA from a grid-connected MHP larger than 20 kW and sold in the rural hills, the NEA incurs a lower cost compared to its cost of delivery from elsewhere. Therefore, the NEA should give preference to drawing power from MHPs and connecting them to the national grid. Recently, NEA's Board of Directors passed the feed-in-tariff (FIT) for MHPs at NPR 4.80/kWh (wet season) and NPR 8.40/kWh (dry season), which are the same rates offered to independent power producers (IPP) of larger hydropower plants. The AEPC should continue to determine FITs for MHPs as a separate case since the current FIT is considerably lower than NEA's cost of delivery and unlike MHPs, small hydropower plants (SHPs) enjoy substantial scales of economy. A local community invests in an MHP only if the GoN is unable to extend the national grid to provide electricity to that area. Therefore, it should be GoN's obligation to safeguard the local community's investments and assets by pursuing a policy of power purchase rather than of abandonment of MHPs. As long as it is financially viable for the community, MHPs should be connected to the grid and their surplus power purchased as a general policy.

20. While the AEPC promotes standalone MHPs, the NEA manages the national grid. As these institutions are under different ministries (AEPC is under the Ministry of Science, Technology and Environment; NEA is under the Ministry of Energy (MoEn)), coordination between them is infrequent. Furthermore, as the NEA's main objective is to function as a commercial entity, grid connection of standalone MHPs is not its priority. Therefore, coordination between the NEA and AEPC requires an active role from the MoEn to facilitate information-sharing and collaboration for planning and implementation. Most importantly, the NEA and AEPC should collaborate to prepare a national rural electrification master plan to harmonize scattered rural electrification programs and to invest resources in a more planned and organized method.

21. Given that an MHP would be in operation for a certain period before the arrival of a grid, the BFIs can better assess the institutional stability and risks in order to arrive at an informed decision on lending. The NEA as a buyer of power is a government-backed institution and therefore the revenue risk is further reduced from the BFIs' perspective. Therefore, the AEPC should promote greater awareness among BFIs regarding financing opportunities for grid connection of MHPs. Given that grid connection of larger MHPs is financially viable, subsidy for grid connection is not required. However, high interest rates deter MHPs from approaching banks for financing. Therefore, the AEPC should support MHFGs by providing credit facilities, where its funds are on-lent by BFIs along with a minimal interest spread (as well as risk guarantees) for grid connection of MHPs.

22. If an MHP acts as an IPP after being connected to the grid and does not serve the local community at

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[8] Deemed generation refers to the energy, which a generating station is capable of generating but cannot generate due to grid outages beyond the control of generating station resulting in spillage of water.

TABLE 3 | Summary of recommendations for enhancing effectiveness of scaling up of micro hydropower applications

Major recommendations	
Scale-up standalone MHPs to reach more off-grid communities	• Returns from MHPs accord economic benefits approximately three times larger than the investment and operating costs. • As SPV- and diesel-based solutions cost twice or thrice more than the cost for delivering the same level of service from a typical MHP in rural Nepal, MHPs should be the first choice to deliver off-grid electrification from a policy perspective.
Promote larger capacity MHPs rather than a new mini-grid	• Financial viability of mini-grids with increase in PLF is heavily dependent on greater utilization of off-peak power. • Mini-grids are not financially attractive since the cost of interconnecting MHPs is very high regardless of their capacities.
Connect MHPs to the grid and purchase surplus power	• For every unit of electrical energy purchased by the NEA from an MHP and sold in the rural hills, the NEA incurs a lower cost compared to transmission from elsewhere. • GoN should safeguard the local community's investments and assets by pursuing a policy of purchase of power rather than of abandonment of the MHP.
Improving technical performance	
Build grid compatible MHPs	• AEPC should ensure that all new MHPs of 50 kW or above have a grid compatible distribution system (to NEA standards) and that end-users are metered.
Make metering mandatory to improve energy efficiency	• Energy-based tariff should be enforced through metering to make more efficient use of electricity and lower peak demand to allow the same MHP to serve more households.
Strengthen quality assurance during manufacturing and installation	• AEPC should carry out a three-stage inspection process during material, in-process and pre-shipment stages to ensure that the quality of the components delivered at site is as per design and material specifications. • Supervision and quality assurance of civil structures, which is usually executed by the community, should be strengthened.
Create a network of local repair service providers	• Given the large installed base of MHPs especially in central and eastern Nepal, AEPC should identify, encourage and nurture local workshops to provide last mile after-sales services.
Install appropriate safety measures to protect against unintentional islanding	• With appropriate safety and control mechanisms, unintentional islanding can be avoided. • Intentional islanding should be used to provide reliable service to consumers of the grid-connected MHP when there is load shedding on the national grid.
Improving financial and economic performance	
Increase access to finance and educate lenders on operational sustainability of standalone MHPs	• Banks and financial institutions (BFIs) should be educated on the operational sustainability of MHPs and the good track record of MHFGs. • AEPC can help reduce interest costs for these communities by initiating a credit fund for MHP.
Reduce costs by benchmarking and standardization	• A thorough engineering based review of the manufacturing process and costing of MHP should be performed to establish cost benchmarks. • Benchmarking should be followed by standardization of MHP components as opposed to the total customization that prevails today for manufactured items.
Grid connection of MHPs to be based on distance to grid and plant size	• Incremental financial analysis should be performed taking into account plant capacity, distances and availability of grid before deciding on connecting an MHP to the grid.
Encourage BFIs to finance grid connection of MHPs	• AEPC should assist in making loan-financing instruments available through BFIs by creating greater awareness about financing of MHP grid connection. • AEPC should not subsidize grid connection costs. Instead, it should make funds available in collaboration with BFIs as low interest loans for MHPs connecting to the grid.
Improving institutional performance	
Reorient micro hydropower planning to aggregate demand and optimize site potential	• The focus of planning for MHPs should be changed from merely meeting the prevailing power requirements of the community to optimizing site potential. When the pre-feasibility study of an MHP is carried out, opportunities to serve more load centers in the vicinity by building a larger power plant should be explored.
Support the micro hydropower industry to expand business into mini hydropower plants	• AEPC should collaborate with the NMHDA to build the capacity of the industry to manufacture and install mini hydropower plants.
Increase institutional footprint of AEPC and support MHFGs to become legal entities	• Efforts should be made post-installation to help MHFGs transition into a legally registered entity (company, cooperative or NGO). MHFG's capacity in preparing business plans, entering into agreements with the NEA, and maintaining book of accounts should be strengthened. • AEPC should set up regional offices especially in areas of expected growth in community electrification and start a process of devolving decision-making. • Technical capacity of RSCs to provide oversight to the project execution should be enhanced through exchange of knowledge and experiences, collective planning of strategies and use of better equipment.
Strengthen pre-qualification process of service providers	• A comprehensive post-installation survey of MHPs should be put in place to verify that the service providers are meeting the required quality at site.
Ensure effective coordination between the NEA and AEPC to harmonize rural electrification programs with grid extension	• The MoEn should play an active role to ensure coordination between the NEA and AEPC to facilitate information sharing and collaboration for planning and implementation. • Since the GoN provides subsidy support both to community based rural electrification (CBRE) and micro hydropower programs, these need to be harmonized such that the subsidies are utilized optimally and MHP-grid interface issues are resolved in a planned way. • The NEA and AEPC should collaborate to prepare a national rural electrification master plan.

all, the rationale for AEPC subsidy (prior to grid connection) would not be justified. On an operational level, such MHPs could be taken over through a lease or even purchased outright by private investors who would make substantial profits. Therefore, an MHP as an IPP with continued responsibility to the local community should be the institutional model supported by the AEPC. Technically, this model would ensure a high PLF of the MHPs as well as continuous supply of electricity to its previous distribution area even during NEA's load-shedding hours. However, this requires adequate safety measures to address high safety risks. One of the major safety issues is the problem of unintentional islanding, which can be potentially hazardous if the grid-connected MHP fails to properly shut down during a grid disturbance. However, with appropriate safety and control mechanisms, intentional islanding should be used to provide reliable service to consumers of the grid-connected MHP when there is load shedding in the national grid. Operators of the MHPs do not receive enough technical training, and therefore, are often uninformed about such operational and safety issues that arise in context of a national grid connection. Therefore, the community's technical and managerial capabilities must be improved through appropriate trainings to prepare them for grid connection.

23. A summary of major recommendations for enhancing the effectiveness of scaling up micro hydropower applications is presented in Table 3.

E. CONCLUSIONS AND WAY FORWARD

24. Overall the study concludes that the AEPC should vigorously pursue scaling up MHPs as standalone installations. Simultaneously, it should work closely with the NEA to gain experience by operationalizing the grid connection of a few pilot MHPs. Based on the experience gained, it should also work on creating an enabling policy and procedure for grid-connection of MHPs. As for mini-grids, the AEPC should support them on a case-by-case basis after carefully assessing the actual demand for off-peak power as well as financial and economic benefits.

25. The AEPC should continue to scale up standalone MHPs by reaching out to off-grid communities in the rural hills of Nepal that will not be served by the national grid for many years to come. It should also work in close coordination with the NEA and the relevant ministries to ensure that the recent decision of the Board of Directors of the NEA to allow MHPs to be grid connected is preserved in the policy. It should also work on modifying the current PPA to include either a "deemed generation" status to MHPs or a guaranteed minimum payment on grid outages hindering evacuation of power from the MHP to the grid.

26. The AEPC should modify its current micro hydropower schemes to include the cost of metering and of building an NEA-standard distribution network in micro hydropower service areas to make them grid ready. Furthermore, it should work in close coordination with donors and BFIs to facilitate a line of credit for grid connection of existing MHPs at low interest rates. NMHDA should work in close cooperation with the AEPC in scaling up of MHPs, streamlining the manufacturing process, cost reduction and quality assurance.

27. Donors could support the AEPC in building capacity to steer a comprehensive policy in the area of grid connectivity of MHPs. Financing grid connection of MHPs will allow donors to channelize funds through the banking sector rather than offering capital subsidies. Grid connection of MHPs will help the NEA gain well organized tariff paying rural customers. In many cases, where the MHP's distribution network is up to NEA standards, the NEA would not need to invest in creating an entirely new distribution network.

28. To enable the first grid-connected MHP under a PPA, the NEA should work with the AEPC to identify a suitable site. Using the experience gained during operationalizing the grid connection of that site, suitable guidelines for grid connection of MHPs could be drawn up by both the AEPC and NEA. Also, these institutions should collaborate to prepare a national rural electrification master plan to harmonize rural electrification programs with grid extension.

01

Micro Hydropower Scenario in Nepal

29. Before the 1960s, diesel-operated mills were used in the hills of Nepal for agro-processing. In the 1960s, small water mills known as "turbine mills" were introduced in Nepal using locally developed turbines as an alternative to diesel-operated mills. By the late 1980s, small generators were added to the turbine mills for lighting the mills at night and supplying surplus power to light a few houses in the vicinity. These turbine mills that were modified to supply electric power were known as micro hydropower plants (MHPs).

30. Since the early 2000s more than 25 MW of micro/mini hydropower schemes have been constructed with support from the Alternative Energy Promotion Center (AEPC) and its various development partners. The Government of Nepal (GoN) in collaboration with development partners that support Nepal's rural and renewable energy sector, designed the National Rural and Renewable Energy Programme (NRREP). The NRREP, being implemented by the AEPC for five years (from 2012 to 2017) as a single program modality, aims to install an additional 25 MW of mini/micro hydropower to provide electricity to an additional 150,000 rural households by 2017.

31. With the Nepal Electricity Authority (NEA; the centrally managed utility responsible for supply of grid electricity in the country) extending its grid to rural areas served by MHPs, the absence of a grid connection policy for MHPs will render such plants redundant. According to a preliminary estimate by the AEPC, the grid is currently approaching 90 MHPs[9] with a total capacity of 2.7 MW and this number is steadily increasing. These plants will have to be shut down and abandoned as their customers switch to the national grid, which supplies power of better quality and does not impose power caps. Due to this trend, invested resources and the hard work of the local community are going to be wasted. Figure 1 shows the map of Nepal with the existing transmission and distribution lines down to 11 kV in MHP areas (i.e. hills and mountains) along with the installed MHPs as of 2013. The Terai region and Dolpa district that do not have substantial MHPs are shaded in the figure to indicate that these regions have been excluded from the geographical analysis. The demand for MHP in Dolpa is low since the operating costs are high due its remoteness and the need to often airlift the equipment. Furthermore, it snows for about six months and the local residents do not have adequate time for community participation due to more lucrative activities, such as harvesting "Yarsagumba" (a highly sought after medicinal herb).

32. In Baglung the grid has reached the northeast part of the district where the interface with the existing MHPs has occurred (Figure 1). The other 17

TABLE 4: | Definitions of micro/mini hydropower plants according to AEPC

Plant type	Definition
Micro hydropower	10 kW to 100 kW
Mini hydropower	100 kW to 1000 kW

[9] Based on data received by the AEPC from its outreach offices (2013)

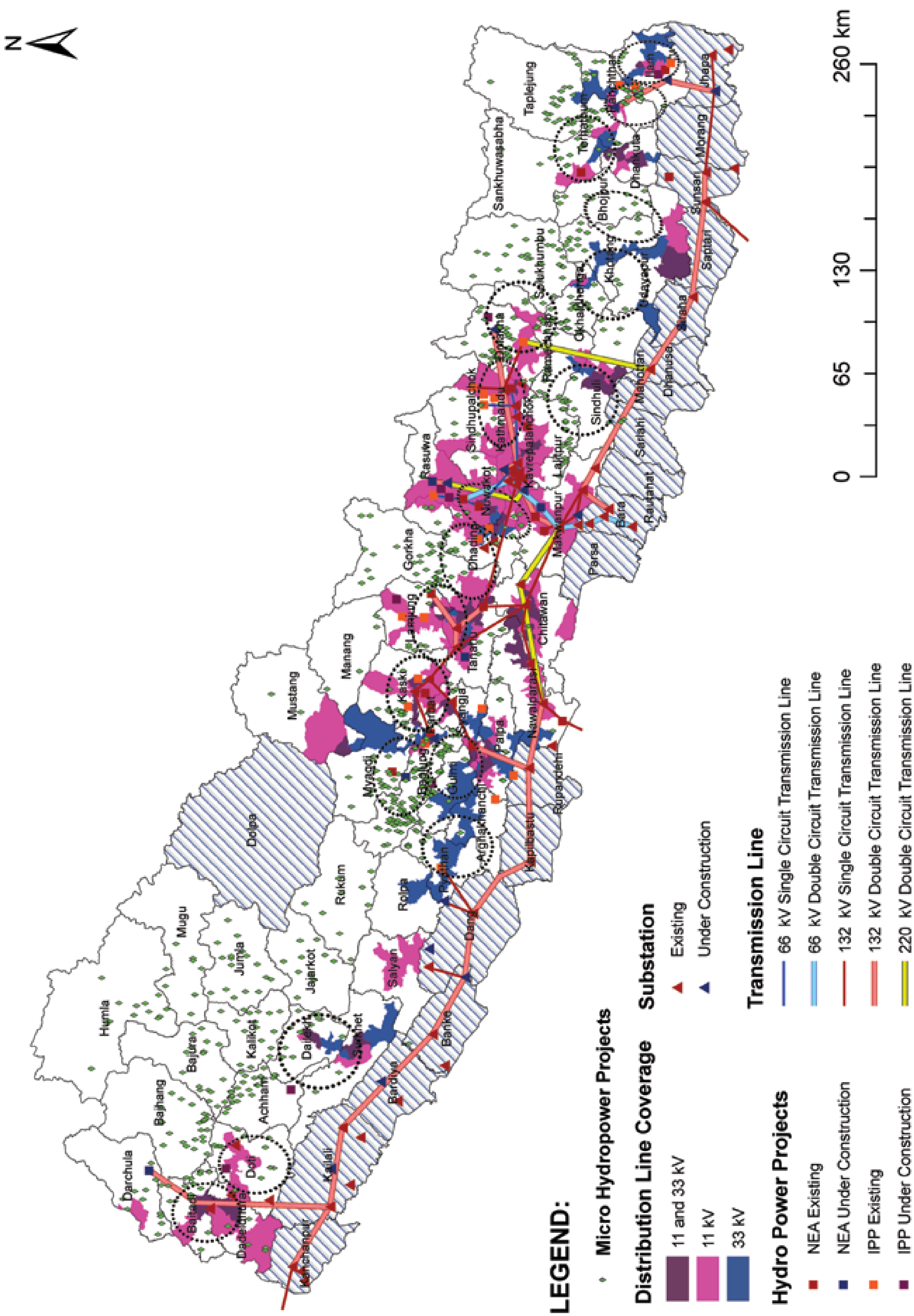


Figure 1: Map of Nepal showing MHP-national grid interface

districts where such interfaces have occurred are: Baitadi, Doti, Dailekh, Pyuthan, Myagdi, Kaski, Lamjung, Gorkha, Dhading, Sindhupalchowk, Kavrepalanchowk, Dolakha, Okhaldhunga, Khotang, Sankhuwasabha, Terathum, and Panchthar.

33. The MHP–national grid interface has created an urgent need for policy level discussion and coordination to avoid duplication of resources, maximize the benefits of investment, and provide sustainable electricity access to the rural population. Technical, financial, managerial/ownership, and community aspects need to be analyzed to propose how isolated MHPs can be sustainably connected to the grid. The adequacy of AEPC and NEA's technical, environmental and policy frameworks, as well as regulatory guidelines have to be reviewed for sustainable promotion of the micro hydropower sector.

1.1. SUMMARY OF REGULATORY AND POLICY ENVIRONMENT

34. Close to 42 percent[10] of the Nepalese population does not have access to grid electricity. Compared to 93 percent of the urban households that are connected to the national grid, only 49 percent of rural households (80 percent of Nepal's population lives in rural areas) have access to the electricity grid.[11] To provide electricity to most of the Nepalese households in rural areas, the GoN has put in place various policies and regulations aimed towards rural electrification. To implement these policies, the AEPC under the Ministry of Science, Technology and Environment (MoSTE) has the major responsibility to provide electricity access in rural areas using renewable energy technologies (RETs) including micro hydropower.

35. The regulatory and policy environment in the micro hydropower sector are based on:

- Water Resource Act, 1992
- Electricity Act, 1992
- AEPC Act formation order
- Hydropower Development Policy, 2001
- Rural Energy Policy, 2006
- Subsidy Policy for Renewable Energy, 2013
- Renewable Energy Subsidy Delivery Mechanism, 2013
- Annual Budget of the Government of Nepal

36. The "Water Resource Act, 1992" allows water mills and water grinders to use water resources without a license. "The Electricity Act, 1992" provisions that no license will be required for hydropower projects of less than 1000 kW capacity as long as they are registered with the District Water Resources Committee and the registration information is sent to the Department of Electricity Development (DoED). Additionally, to expedite the development of MHPs, these projects are exempted from paying any income tax.

37. According to the Alternative Energy Development Committee Formation Order of the GoN, the AEPC was established in 1996 as a line agency under the MoSTE. The AEPC's mandate is to promote alternative energy, set and monitor technological standards, and coordinate with international donors and local government bodies to implement alternative energy programs/projects in rural areas. The Formation Order also states that the AEPC should take on the role of a national focal agency in the alternative energy sector, encourage private sector participation, and ensure an environment that is conducive to facilitating loans through financial institutions and channelizing government subsidy.

38. "The Hydropower Development Policy, 2001" foresees generating low cost electricity and extending reliable and quality electricity services throughout the country. In addition, it plans to tie-up electrification with economic activities by operating small and mini hydropower projects at the local level to develop the rural economy. It focuses on rural electrification to support agricultural and industrial development of rural areas. It envisions that rural mountainous areas not catered by the national grid would be supplied by these small/mini hydropower projects.

39. "The Rural Energy Policy, 2006" makes the participation of local bodies such as village development committees (VDCs) and district development committees (DDCs) mandatory and creates a Rural Energy Fund for subsidy mobilization at the central, district and village levels. As a result, community-based energy planning and social mobilization are initiated. In addition, the policy promotes private sector participation in RETs.

[10] National Planning Commission (2014)

[11] Nepal Labour Force Survey (2008)

40. "Subsidy Policy for Renewable Energy, 2013" aims to increase access to RETs in remote parts of the country inhabited by the poorest and most socially disadvantaged people. It encourages the private sector to commercialize RETs and focus on better quality and service delivery in rural areas. The "Renewable Energy Subsidy Delivery Mechanism, 2013" was prepared by the MoSTE. Under this delivery mechanism, the AEPC evaluates the technical and financial feasibility of MHPs by providing financial support to conduct a detailed feasibility study of potential MHP sites.

41. The GoN has included financial support for rural energy development through its "Annual Budget" since its sixth five-year plan (1980–85). The National Planning Commission (NPC) is the advisory body responsible for formulation, resource allocation, implementation, and monitoring and evaluation of development plans. The annual budget of 2013 allocated NPR 540 million for continuation of subsidy to MHPs implemented by communities, cooperatives and firms. This amount was allocated to install an additional 4,500 kW of generation capacity to cater to the electricity needs of 30,000 unelectrified households.

1.2. EFFORTS AND INITIATIVES IN NEPAL

42. In its 5th development plan (1975–80), the GoN committed to develop the micro hydropower sector. As a part of the 6th development plan (1980–85), the Agricultural Development Bank Limited (ADBL) launched the "Rural Electrification Project" and started promoting electricity generation from MHPs by providing 50 percent subsidy on the cost of the electromechanical equipment. In the 7th development plan (1985–90), the GoN recognized the importance of alternative energy technologies and promoted MHPs as a tool for developing the agriculture sector and small-scale industries. The 8th development plan (1992–97) gave special priority to the energy sector with an emphasis on reducing the gap between urban and rural areas.

43. The AEPC was established during this period as a body of the GoN and the Rural Energy Development Programme (REDP) was initiated with support from the United Nations Development Project (UNDP) and the World Bank. The 9th development plan (1997–2002) emphasized the need for developing MHPs for economic development and environmental protection with clear policy formulation directives and targets. The 10th development plan (2002–07) set clear targets for alternative energy and aimed to increase the rural population's access to energy from 7 percent to 12 percent. The 11th development plan (2007–10) aimed to increase this access by another 5 percent. The 12th development plan (2010–13) promoted the development of MHPs under the leadership of the local government and aimed to increase rural energy access by an additional 7 percent. The 13th three-year plan (2013–16) aimed to enhance the capacity of local bodies to plan, implement, promote, monitor and evaluate RETs and increase rural population's access to energy by an additional 7 percent.

44. Due to the subsidy policy for micro hydropower schemes, the number of stakeholders in the micro hydropower sector including feasibility study consultants, micro hydropower equipment installers, and public as well as private professionals has steadily increased. With support from the AEPC and its various development partners, since early 2000 more than 25 MW of micro/mini hydropower schemes have been constructed.

45. Various institutions have taken initiatives, which have resulted in the growth of the micro hydropower sector (see Annex 1). The World Bank approved a Power Development Project consisting of a US$75.6 million International Development Association (IDA) credits in 2003 to assist the GoN in meeting its power sector objectives. A complementary Carbon Offset Project to provide additional financial support to AEPC's Nepal Village Micro Hydro Program (NVMHP) was established. The Carbon Offset project complements the ongoing World Bank Power Development Project by providing additional support for improving access to electricity services for rural areas. The Micro Hydro Village Electrification component received US$22 million in assistance (US$19.36 million IDA Grant and US$1.94 million TA). The NVMHP received US$1.96 million (funded by a Trust Fund) from 2007 to 2015.

46. In the 1990s, Practical Action then known as Intermediate Technology Development Group

(ITDG) was actively involved in promoting micro hydropower technology including financing site installations of pilot projects. Practical Action is currently involved in advancing climate resilient energy access planning and implementation; increasing private sector participation in the energy access market; mobilizing demand for energy services in marginalized communities; introducing minimum energy standards for energy access; and ensuring productive end-use of energy for sustainable livelihood of poor households. It aims to demonstrate a decentralized energy system with particular focus on achieving minimum energy standards and total energy access to attain universal access to energy by 2030.

47. The Annapurna Conservation Area Project (ACAP) under the National Trust for Nature Conservation (NTNC) has also played a significant role in promoting micro hydropower technology in the Annapurna conservation area. MHPs such as the 50 kW Ghandruk and 80 kW Bhujung are examples of plants implemented with support from the ACAP that are functioning well.

48. As part of its rural electrification program, the GoN has established the community based rural electrification (CBRE) program, which is implemented by the NEA. At the request of the community, the NEA extends the national grid to rural areas under this program. Funds for grid extension are made available to the NEA through 90 percent subsidy support from the GoN provided that the community contributes the balance of 10 percent. However, there is no long-term grid extension master plan and grid extension is planned on an annual basis.

1.3. OBJECTIVES OF THE WORLD BANK TECHNICAL ASSISTANCE

49. The following are the objectives of this technical assistance.

- Investigate the performance and sustainability aspects of off-grid mini/micro hydropower sectors based on lessons learnt from ongoing projects and best practice models in the country and internationally.
- Investigate the technical, financial, regulatory, economic and socio-environmental considerations, barriers and opportunities for scaling up micro hydropower energy access by establishing mini-grids and integrating such mini-grids to the national grid as per GoN's vision and prospective plans.
- Identify gaps and suggest improvements in the AEPC's and NEA's institutional and technical capacity for scaling up micro hydropower access, including available standards, a regulatory environment, and quality assurance mechanisms.
- Provide strategic and innovative recommendations for scaling up micro hydropower access in a sustainable manner.

1.4. STUDY APPROACH AND METHODOLOGY

50. To prepare a roadmap on up-scaling MHPs, it is necessary to analyze them from regulatory/policy, institutional, technical, financial, managerial and community perspectives. Therefore, the study approach and methodology have been formulated such that the impacts of these issues can be analyzed.

51. To identify policy barriers for up-scaling and grid connection of MHPs, officials from AEPC, NEA, World Bank, Nepal Micro Hydropower Development Association (NMHDA), as well as surveyors, manufacturers and installers were consulted using structured questionnaires and informal discussions. International best practices in the context of grid connection of MHPs were also reviewed. AEPC's approach to promoting micro hydropower was analyzed. Possible interventions to overcome policy hindrances were also discussed. Additionally, the changes in AEPC's subsidy policy and its implications on the micro hydropower sector were analyzed by tallying the number of MHPs constructed during each subsidy policy period, i.e. 2000–06, 2006–09 and 2009–13.

52. To understand the technical issues, recent technical innovations and their implications in distributed generation management were reviewed. Furthermore, technical solutions for grid connection

of MHPs (and mini-grid) to the national grid were analyzed. Existing NEA grid codes and a new set of grid connection standards for MHPs prepared by the AEPC called "Micro Hydro Projects Interconnection Equipment Standards and Specification, 2013" were reviewed. Technical problems prevalent in the visited MHPs were investigated.

53. To conduct a financial study of the micro hydropower sector, the current financial status of visited MHPs were studied. Marginal costs for mini-grid construction and grid connection were analyzed where relevant. Marginal revenues from selling electricity to the grid after grid connection were studied. A financial analysis of the proposed business models was carried out. Additionally, the value of anchor, business and community customers of MHPs were investigated in the context of financial viability. The basis for setting NEA's buy-back rate (feed-in-tariff (FIT) for MHPs) was reviewed. Issues raised by the NEA regarding technical and financial feasibility of the MHP grid connection were also studied. Finally, operational processes, resource flows and the project cycles of micro hydropower companies (surveyors, manufacturers and installers) were reviewed to identify current barriers and recommend measures for financial efficiency.

54. To perform a managerial and community study of the micro hydropower sector, the prevalent managerial approaches, business models and management solutions were studied. Methods to facilitate collective action of the community were analyzed using the Institutional Analysis and Development framework. Micro hydropower related services provided by regional service centers (RSCs) and local partner organizations (LPOs) under the NRREP were reviewed. Institutional mechanisms for strategic guidance and technical back-stopping for further up-scaling of MHPs were discussed.

55. Field visits were conducted to corroborate the study approaches mentioned above. The field visits included isolated MHPs, mini-grid systems and (previously) grid-connected MHPs. Isolated MHPs outside the AEPC system were also visited. Similarly, site visits were also made to CBRE entities. The details of the sites visited in the course of this study are presented in Annex 2 and also summarized in Chapter 3. Additionally, various stakeholders in the MHP industry including surveyors, manufacturers, installers, and RSCs were visited to understand key issues in the MHP sector.

56. Two workshops, one during the inception phase and another after completion of the draft report, were conducted to incorporate the views of various stakeholders and organizations involved in the micro hydropower sector, such as AEPC, NEA, NMHDA, non-governmental organizations (NGOs), international NGOs (INGOs), surveyors, manufacturers and installers.

1.5. STRUCTURE OF THE REPORT

57. The micro hydropower scenario in Nepal including the regulatory and policy environment, initiatives undertaken, objectives of this Technical Assistance (TA) and study approach and methodology adopted have been described in this chapter. Assessments of the micro hydropower policy and regulations including the subsidy policy and delivery mechanism, institutional architecture and project cycle, role of NEA in micro hydropower and analysis of policy and institutional issues are presented in Chapter 2. Chapter 3 discusses scaling up of MHPs as standalone, mini-grid and grid connected systems. For each of the systems, technical reliability, ability to meet power needs, financial reliability, economic benefits, management structures and support systems have been analyzed. Chapter 4 presents the findings from this study, recommendations to address these issues and the way forward. Supporting details, data and data analyses undertaken during the course of this study are presented in the Annexes.

02

Assessing the Policy and Regulatory Framework for Micro Hydropower in Nepal

2.1. MICRO HYDROPOWER POLICY AND REGULATIONS

58. Policy and regulations relevant to the micro hydropower sector have been discussed earlier in Chapter 1. Analyses of these policies are presented in this chapter. Section 2.2 assesses the role of subsidy and its impact on micro hydropower sector growth. The institutional architecture and project cycle are discussed in Section 2.3. Section 2.4 presents the role of NEA in micro hydropower especially in the context of the MHP–grid interface. Finally, Section 2.5 presents the analysis carried out on policy and institutional issues.

2.2. SUBSIDY IN MICRO HYDROPOWER

59. High costs of renewable energy systems and the insufficient capital of rural populations are major barriers in implementing RETs in rural Nepal. Therefore, the subsidy for RETs has been instrumental in providing clean energy solutions to rural areas at lower investment by the communities. Due to the subsidy support many rural areas are able to access modern clean energy, and promote local entrepreneurship and economic development.

60. Subsidy for micro hydropower development is provided by the GoN (through donor support) and implemented through the AEPC based on:

- Subsidy Policy for Renewable Energy, 2013.
- Renewable Energy Subsidy Delivery Mechanism, 2013.

61. The AEPC's updated "Subsidy Policy for Renewable Energy, 2013" has the main objective of increasing access to RETs in very remote parts of the country inhabited by the poorest and most socially disadvantaged people. The current subsidy policy encourages the private sector to commercialize

TABLE 5: | Current subsidy for micro hydropower implementation

Subsidy Category	Subsidy for Micro Hydropower Project (in NPR*)		
	Category "A" VDCs	Category "B" VDCs	Category "C" VDCs
Subsidy per household	25,000	25,000	25,000
Subsidy per kW	130,000	100,000	70,000

*NPR 1 = US$0.0104

Note: The maximum subsidy amount per kW (including household subsidy) will not exceed NPR 255,000 for Category "A", NPR 225,000 for Category "B", and NPR 195,000 for Category "C" VDCs. For possibility of productive end-use in the future, subsidy for additional 1 kW per maximum of 5 households will be provided.

RETs, and focus on better quality and service delivery in rural areas. Table 5 and Table 6 show the current subsidy available for micro and mini hydropower implementation respectively. Category "A", "B" and "C" VDCs imply very remote, remote and accessible VDCs respectively as defined by the GoN.

62. The "Renewable Energy Subsidy Delivery Mechanism, 2013" was prepared by the MoSTE according to the Renewable Energy Subsidy Policy, 2013 and approved by the Financial and Infrastructure Committee of the Parliament. The AEPC evaluates the technical and financial feasibility studies for projects with capacity of more than 10 kW MHPs. For lower capacity plants (pico hydropower), the District Environment, Energy and Climate Change Section (DEECCS) evaluates and approves of feasibility studies. This initiative was taken by the AEPC to devolve powers to district level organizations.

63. The AEPC provides financial support for carrying out a detailed feasibility study of the new MHPs. Up to 80 percent of the total feasibility study cost is subsidized by the AEPC (see Table 7).

64. The subsidy policy and the subsidy delivery mechanism changed in the years 2000, 2006, 2009, and most recently in 2013. Subsidy for an MHP has increased and the delivery mechanism has been updated with each policy change. The changes in subsidy amount are presented in Table 8.

65. Figure 2 presents the impact of the annual subsidy amount on the annual increase in aggregate MHP capacity installed. The annual subsidy amount and the installed capacity do not have a good correlation when both parameters are compared for the same year.

66. Assuming that the impact of the subsidy disbursed is reflected in the installed capacity after a time gap (i.e. subsidy disbursement and construction of MHPs will require time), the subsidy amount was brought forward by one to five years. The best fit occurred when the shift was made by two years. The updated graph in Figure 3 (with a shift by two years) shows a strong correlation between the annual subsidy amount and the installed capacity. Therefore, it is expected that, on average, approximately two years are required for the subsidy to have an impact on installed capacity. The figure implies that once the feasibility study of an MHP is approved (i.e., project is at a "ready to go" stage) and subsidy disbursements are made, the power plant becomes operational within two years.

TABLE 6: | Current subsidy for mini hydropower implementation

Subsidy Category	Subsidy for Mini Hydropower Project (in NPR*)		
	Category "A" VDCs	Category "B" VDCs	Category "C" VDCs
Subsidy per household	20,000	18,000	16,000
Subsidy per kW	120,000	100,000	70,000

*NPR 1 = US$0.0104

Note: The maximum subsidy amount per kW (including household subsidy) will not exceed NPR 220,000 for Category "A", NPR 190,000 for Category "B", and NPR 170,000 for Category "C" VDCs; Projects with capacity from 100 kW to 500 kW must connect at least 500 households or 5 households per kW, and projects with capacity from 500 kW to 1000 kW must connect at least 1000 households or 5 households per kW to be eligible for subsidy.

TABLE 7: | Current subsidy for feasibility study of hydropower projects

Location	Subsidy for Detailed Feasibility Study (in NPR*)		
	10 kW–50 kW	50 kW–100 kW	100 kW–1000 kW
Category "A" VDCs	225,000	295,000	1,200,000
Category "B" VDCs	200,000	275,000	1,100,000
Category "C" VDCs	175,000	250,000	1,000,000

*NPR 1 = US$0.0104

TABLE 8: | Changes in subsidy amount with change in policy

Particulars	Year of Subsidy Policy			
	2000	2006	2009	2013
Micro hydropower	NPR* 70,000/kW	NPR 10,000/HH not exceeding NPR 85,000/kW	NPR 15,000/HH not exceeding NPR 125,000/kW	Category A VDC: NPR 25,000/HH and NPR 130,000/kW not exceeding NPR 255,000/kW Category B VDC: NPR 15,000/HH and NPR 100,000/kW not exceeding NPR 225,000/kW Category C VDC: NPR 15,000/HH and NPR 70,000/kW not exceeding NPR 195,000/kW
Community/ Cooperative Owned MHP				Category A VDC: NPR 20,000/HH and NPR 120,000/kW not exceeding NPR 220,000/kW Category B VDC: NPR18,000/HH and NPR 100,000/kW not exceeding NPR 170,000/kW Category C VDC: NPR 16,000/HH and NPR 70,000/kW not exceeding NPR 170,000/kW
Grid-connected MHP				NPR 15,000/HH
Electricity Add-on	NPR 27,000/kW	NPR 6,000/HH not exceeding NPR 60,000/kW	NPR 6,000/HH not exceeding NPR 60,000/kW	Category A VDC: NPR 8,000/HH and transportation subsidy of NPR 20,000/kW not exceeding NPR 90,000/kW Category B VDC: NPR 7,000/HH and transportation subsidy of NPR 10,000/kW not exceeding NPR 80,000/kW Category C VDC: NPR 6,000/HH and transportation subsidy of NPR 5,000/kW not exceeding NPR 70,000/kW
Rehabilitation	50 percent of the cost not exceeding NPR 35,000	NPR 10,000/ incremental HH not exceeding NPR 85,000	50 percent of the cost not exceeding NPR 62,500/kW	NPR 10,000/kW not exceeding NPR 200,000/plant for minor damage to civil structure NPR 50,000/kW not exceeding NPR 1,000,000/plant for major damage to power house or rehabilitation of old mini/micro hydropower supported by GoN

*NPR 1 = US$0.0104; HH = household

66. Assuming that the impact of the subsidy disbursed is reflected in the installed capacity after a time gap (i.e. subsidy disbursement and construction of MHPs will require time), the subsidy amount was brought forward by one to five years. The best fit occurred when the shift was made by two years. The updated graph in Figure 3 (with a shift by two years) shows a strong correlation between the annual subsidy amount and the installed capacity. Therefore, it is expected that, on average, approximately two years are required for the subsidy to have an impact on installed capacity. The figure implies that once the feasibility study of an MHP is approved (i.e., project is at a "ready to go" stage) and subsidy disbursements are made, the power plant becomes operational within two years.

67. Due to this two-year shift, the impact in the number and capacity of MHPs installed would become visible only after two years from the disbursement of the subsidy. This is important when comparing impacts of subsidy in the transition years when the subsidy policy itself has been revised. For example, the change in subsidy policy of 2000 should impact installed capacity and number in 2002–07, 2006 in 2008–10, and 2009 in 2011–14. Similarly, the impact

Figure 2: **Impact of subsidy on installed capacity (when compared at same base year)**

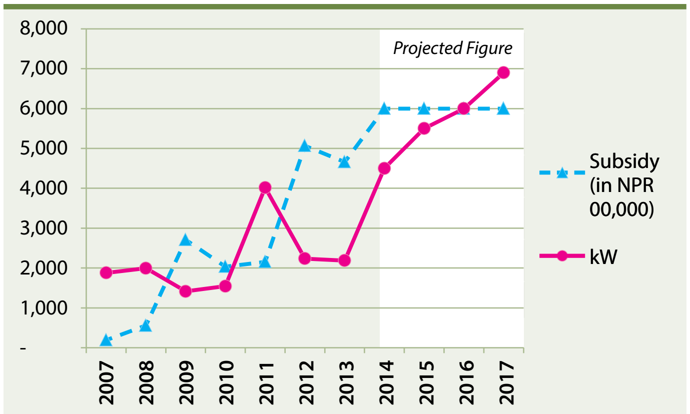


Figure 3: **Impact of subsidy on installed capacity with two years shift**

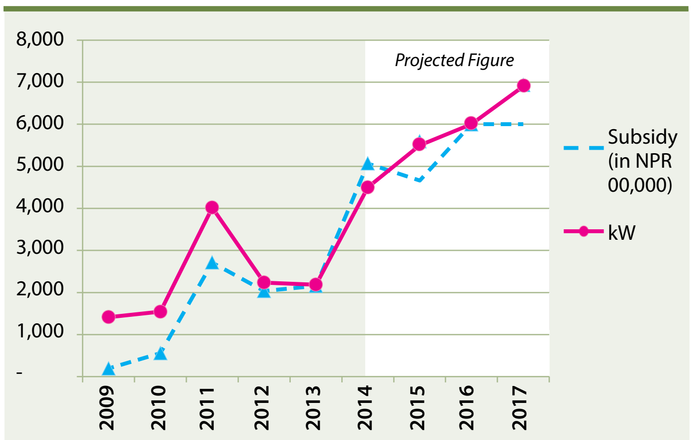
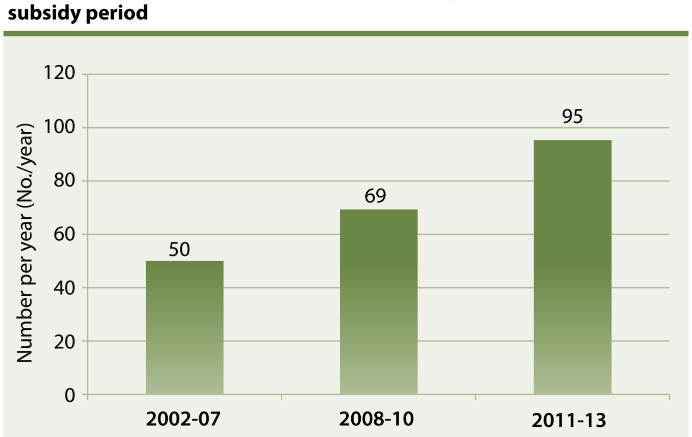


Figure 4: **Average number of MHPs added each year during each subsidy period**



of the subsidy policy of 2013 will be seen from 2015 onwards. Figure 4 shows the annual rate of increase in number of MHPs installed during the three subsidy periods. Figure 5 shows the annual rate of increase in aggregate capacity of MHPs installed during the subsidy periods.[12]

68. As can be seen from these figures, the annual rate of the number and capacity of MHPs added have increased steadily for each subsidy impact period. Therefore, the changes in subsidy seem to be progressive with each change bringing an increase in the rate at which the micro hydropower sector is growing.

69. Similarly, with the change in each subsidy policy in 2000, 2006 and 2009, the average plant size has also been increasing. During 2002–07, 2008–10 and 2011–13, the average plant sizes were 17 kW, 24 kW and 30 kW, respectively as seen in Figure 6.

2.3. INSTITUTIONAL ARCHITECTURE AND PROJECT CYCLE

70. The institutional architecture of the micro hydropower sector with the micro hydro functional group (MHFG) as the focal point is presented in Figure 7.

2.3.1. INSTITUTIONAL ARCHITECTURE

71. As mentioned earlier, the AEPC is the national focal agency for promoting alternative energy in Nepal. It also works closely with the private sector and adopts a demand-based approach. The AEPC focuses on capacity building, technical and financial assistance, and coordination and quality assurance, whereas the private sector is involved in consulting, manufacturing, supply and installation, and after-sales services. However, the private sector does not make investments in the infrastructure (i.e. MHPs) since they are not viewed as profitable and also because since 2006 the AEPC has been following a policy of channelizing subsidies for MHPs solely to community groups.

72. In the public sector, the MoSTE works at the policy level and the AEPC works as the national executing organization. The 75 DEECCSs monitor and

[12] AEPC (2013

supervise projects supported by the AEPC at the district level. There are nine RSCs (NGOs, private companies and cooperatives) that assist the communities in implementing the projects on the ground.

73. In the private sector, the AEPC has pre-qualified a number of companies that enables them to be involved in consulting (survey and design), manufacturing, supply and installation of MHPs. In order to receive subsidy support, communities need to engage AEPC pre-qualified companies to implement micro hydropower projects. At the national level, the AEPC works closely with donor agencies, related ministries, their departments, NGOs, private sector, civil society, national banking institutions, academic institutions and community/users groups for the development and promotion of RETs in the country.

74. As of 2012/13 fiscal year, the AEPC had 35 permanent staff members of whom 10 were involved in coordinating and managing the executive portfolio of programs. Additionally, 75 staff members were directly engaged in the NRREP and Renewable Energy for Rural Livelihood (RERL) to support the AEPC in achieving stipulated targets. There were 350 professional staff members employed in nine RSCs and two national service providers (NSPs). The NSPs are involved in supporting improved water mills.

75. The NEA's role within the institutional architecture becomes relevant if MHPs need to connect to the national grid. The role of the NEA in this context is discussed further in Section 2.4.

2.3.2. PROJECT CYCLE

76. The community is the focal point within the institutional architecture and needs to play an active role to implement MHPs. The micro hydropower project cycle flowchart is shown in Figure 8 and discussed hereafter. As a first step of the project cycle, the community interested in building an MHP fills and submits a requisition form to the RSC or DEECCS. A preliminary feasibility study is then carried out by the RSC or DEECCS. In some cases, the pre-qualified consultants also carried out the preliminary feasibility study. The community then requests three sealed quotations from pre-qualified

Figure 5: Average MHP capacity added (kW/year) during each subsidy period

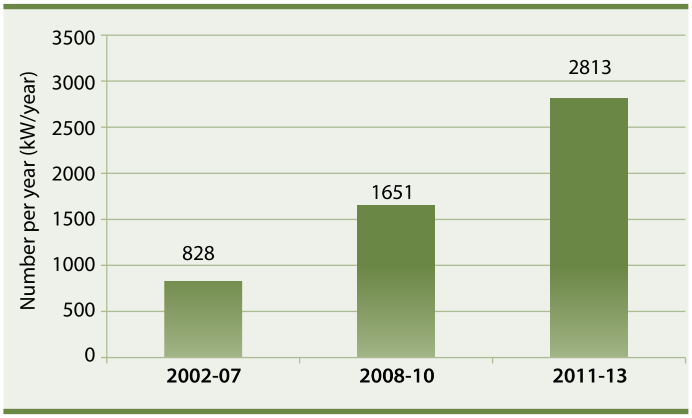


Figure 6: Average plant capacity (kW) added during each subsidy period

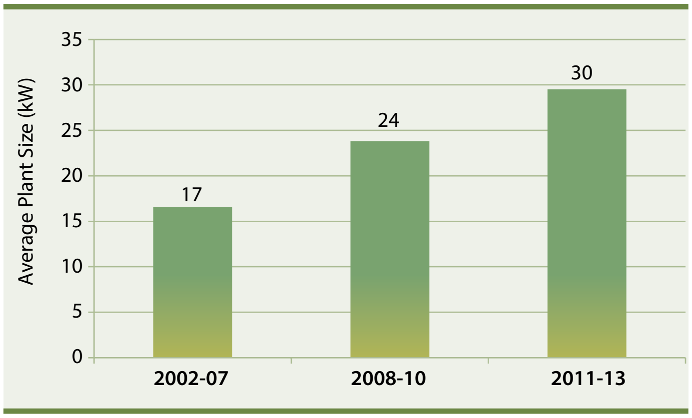
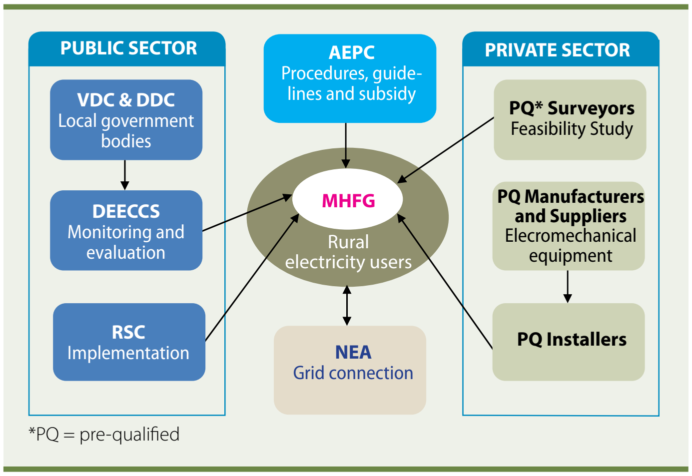


Figure 7: Institutional architecture of the micro hydropower sector



consultants for detailed survey and design on the basis of which a detailed feasibility study (DFS) report is prepared.

77. From the three sealed quotations, one company is selected on a competitive basis by the MHFG. The selected company prepares the DFS report. The RSC examines and assesses the DFS and forwards it to the AEPC along with a letter of recommendation from the DDC. At this time 40 percent of subsidy for survey and DFS is provided and another 40 percent is disbursed after the recommendation of the Technical Review Committee (TRC). The remaining 20 percent subsidy is only provided if the project is approved for implementation. The selected pre-qualified consultant must visit the site at least twice to ensure that construction is being done according to the DFS and submit a quality monitoring report as well as drawings of the project.

78. To apply for subsidy, the community registers a users' group such as a MHFG, cooperative or a private company. Next, a project business plan and a detailed project design (incorporating community and environmental aspects) are submitted to the AEPC. Micro hydropower projects need to obtain a certificate of registration for preferential water use directly from the District Water Resources Committee (DWRC), whereas mini hydropower projects need to obtain a certificate of survey information from the DoED.

79. A bank statement for the equity amount deposited should be submitted along with the project proposal. If a loan agreement with a bank is concluded, a supporting letter from the concerned bank should also be submitted. Additionally, if the local government body is providing financial support, then a letter mentioning the same should also be submitted.

80. To determine the capacity of the project for subsidy purposes, a standard of 200 W/household (maximum allowed 400 W/ household) is used. After the community assures funds (including subsidy) up to 75 percent for micro hydropower and 90 percent for mini hydropower of the total cost, the community signs a contract agreement with the pre-qualified installation company. The proposal should demonstrate that at least 10 percent electricity would be used by the Productive Energy Uses (PEU; a component of the NRREP).

81. The AEPC then reviews and evaluates the submitted documents and recommends it to the Central Renewable Energy Fund (CREF) for approval of subsidy. The AEPC provides the necessary technical support to ensure quality of under-construction projects by mobilizing local bodies (e.g., DEECCS and RSCs).

82. Up to 60 percent of the subsidy amount is released in advance to the installation company against a bank guarantee. Following this, up to another 20 percent of the subsidy is released after a successful test operation for 72 hours (continuously), and the submission of a report to this effect is handed over to the local community (post verification that 75 percent planned households have electricity). Additional subsidy can also be provided at this stage to electrify more households. After the generation of electricity, verification of connected households, the submission of generation test and related handover report, the CREF releases an additional 10 percent subsidy amount. Finally, after one year of successful operation and if all (100 percent) of the planned households are electrified, the CREF releases the remaining 10 percent on recommendation by the AEPC and the community.

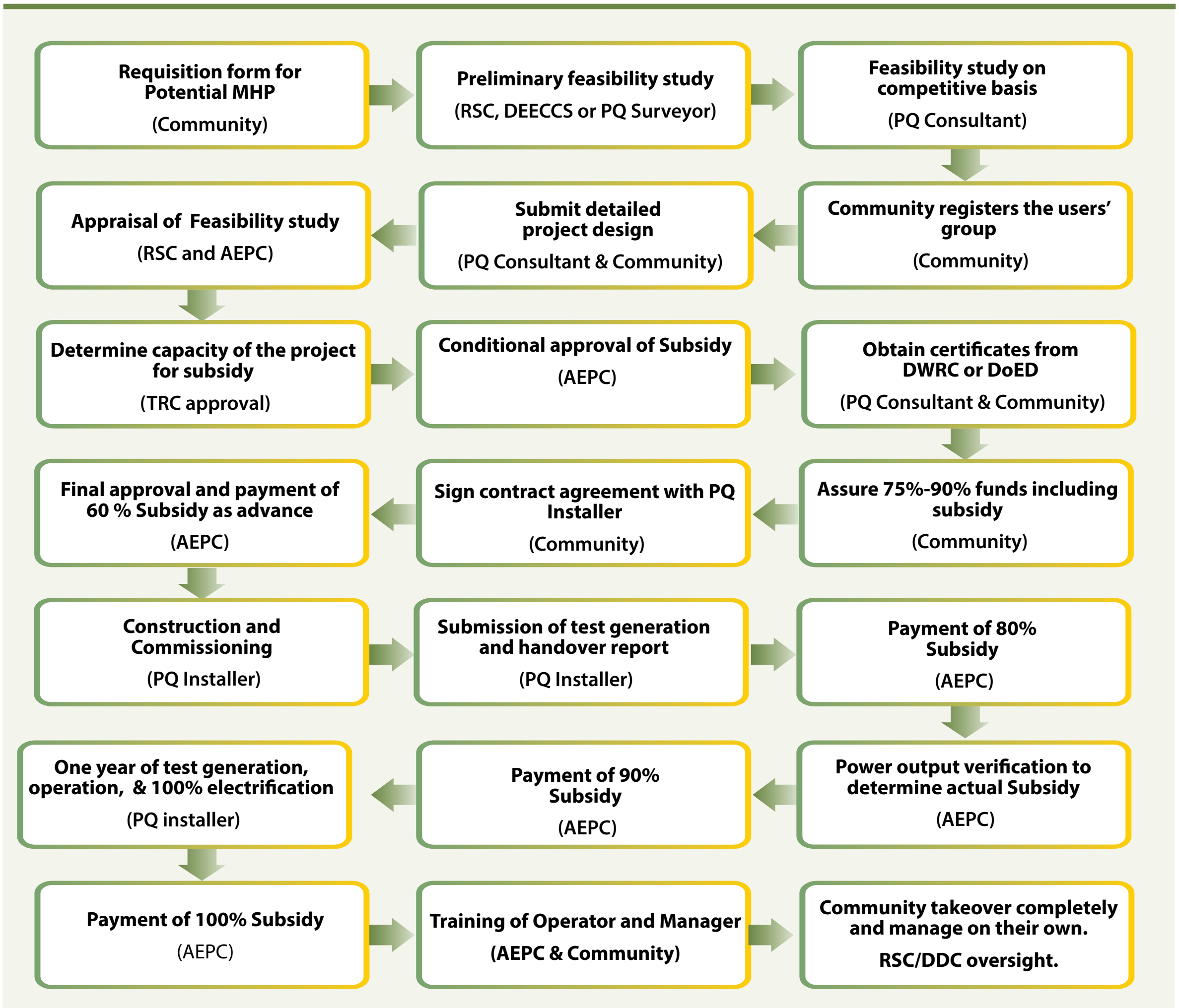
2.3.3. MONITORING AND EVALUATION

83. For MHPs, the AEPC conducts electricity generation and household verification with support from independent (and pre-qualified) consultants (also known as power verification consultants) in the presence of members of RSC, DEECCS and the community. Additionally, the AEPC evaluates the project impact and user satisfaction every two years through independent consultants.

2.4. ROLE OF THE NEA IN THE MICRO HYDROPOWER SECTOR

84. Prior to NEA's establishment, the Department of Electricity of the Ministry of Water Resources, Nepal Electricity Corporation and other related develop-

Figure 8: Micro hydropower project cycle flow chart



ment boards were responsible for managing the generation, transmission and distribution of electricity nationwide. To achieve efficiency and a reliable service to remedy the inherent weakness associated with fragmented electricity organizations due to overlapping and duplication of works, it became necessary to establish an individual organization. Thus, the NEA was established on August 16, 1985 under the Nepal Electricity Authority Act 1984 through a merger of the various institutions involved in electricity generation, transmission and distribution.

85. The main objective of the NEA is to generate, transmit and distribute adequate, reliable and affordable power by planning, constructing, operating and maintaining all generation, transmission and distribution facilities in Nepal's interconnected or isolated power system. NEA's other major responsibilities are to recommend long-term and short-term plans and policies in the power sector to the GoN and to determine the tariff structure for electricity consumption (with prior approval from GoN).

86. When the national grid reaches isolated micro hydropower distribution areas, then such interfaces will require coordination between the AEPC and NEA. As discussed earlier, it is estimated that the national grid has already reached distribution areas consisting of over 90 MHPs with an aggregate capacity of 2.7 MW. Figure 1 shows 18 districts where the NEA's national grid has reached or is about to reach isolated micro hydropower distribution areas.

87. The Electricity Act, 1992 requires the NEA to compensate the power plant once the national grid reaches the micro hydropower distribution area. However, the management of lower capacity MHPs is cumbersome. Until recently, the NEA was reluctant to connect MHPs of less than 100 kW. Therefore, the MHP would be shut down once the NEA grid reached its distribution area. This practice takes away the opportunity of the community to develop its capacity to produce its own electricity and benefit financially.

88. The NEA has recently shown willingness in connecting isolated MHPs to the grid provided that: (a) a grid connection of MHPs does not add financial liabilities to the NEA, (b) MHPs are of "grid-ready" quality and do not create safety problems to the grid itself, and (c) only MHPs with synchronous generators (as compared to induction generators) are connected to the national grid to balance the reactive power needs.

89. Currently the NEA is considering grid connection of MHPs or mini-grids lower than 100 kW. The minimum criteria are that the micro- or mini-grid must use synchronous generators and seek prior authorization from the NEA for interconnection facilities. Furthermore, the NEA is considering provision of MHPs or mini-grids up to 100 kW capacity with the same FIT as the posted rate for hydropower projects up to 25 MW, i.e. NPR 4.80/kWh (wet season) and NPR 8.40/kWh (dry season). If these policy changes come into effect, it could benefit a number of MHPs of less than 100 kW capacity that are facing (or will face) grid interface problems. The new NEA policy changes are expected to be applicable to MHPs with capacities between 100 kW to 500 kW as well.

90. There have been a number of interactions between the NEA and AEPC regarding grid connection of MHPs to solve grid connection issues. The AEPC has prepared a document to standardize MHP grid connection called "Micro Hydro Projects Interconnection Equipment: Standards and Specification, 2013." The action committee in the NEA has agreed to evaluate this document and provide feedback and/or approval. Based on the final version of the standards and specifications, the NEA will provide approval for MHPs to be grid connected.

2.5. ANALYSIS OF POLICY AND INSTITUTIONAL ISSUES

91. Incomplete regulations regarding renewable energy are hindering the up-scaling of MHPs. Although many policies to upscale RETs have been put in place, full-fledged implementation of such policies is not possible without promulgating the corresponding acts. For example, the Rural Energy Policy was formulated in 2006 but the corresponding act such as the Rural Energy Act has not yet been formulated. Similarly, the Water Resource Act (1992) and the Electricity Act (1992) precedes the Hydropower Development Policy (2001). Therefore, these acts need to be updated to support smoother implementation of the policy. Furthermore, important acts related to renewable energy development such as the Feed-In-Tariff Act and the Alternative

Box 1: LINE MINISTRIES OF AEPC AND NEA

The AEPC promotes MHPs whereas the NEA manages the national grid (along with generation and distribution). As both institutions are under different ministries (AEPC is under the Ministry of Science, Technology and Environment and NEA is under the Ministry of Energy (MoEn)), coordination between them is infrequent. Furthermore, as the NEA's main objective is to cater to a wider consumer base and function as a commercial entity, grid connection of isolated MHPs is not its priority.

Coordination between the NEA and AEPC requires an active role from the MoEn. The MoEn facilitating interactions between NEA and AEPC could ensure a closer coordination between these two institutions. It should be noted that the NEA does not formulate policies but implements them under the directives of the MoEn. Moreover, since there is no rural electrification master plan, the AEPC and NEA are not aware of each other's current plan.

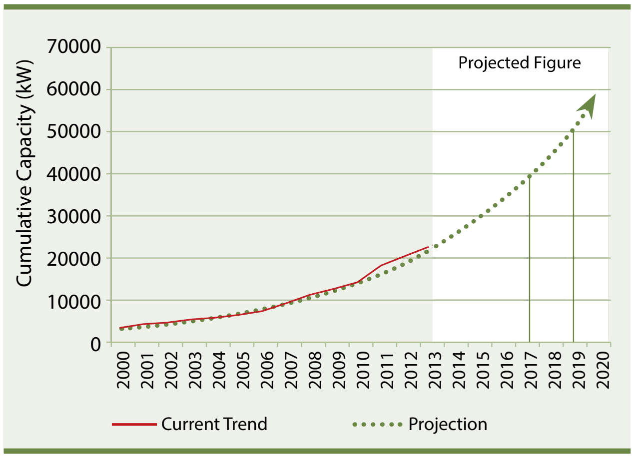
Energy Promotion Board Act have yet to be approved by the parliament. Since the current parliament (which is also the Constituent Assembly) has prioritized the drafting of the country's constitution, parliamentary discussions on approving these acts have been scarce.

92. Sections 29 and 30 of the Electricity Act, 1992 (see Annex 3) requires the NEA and other distribution companies to compensate the existing MHP if they encroach upon the MHP's distribution area. However, this act is seldom enforced and even in rare cases that it is enforced, it promotes buying and then abandoning the MHP, rather than connecting it to the grid to safeguard government investment.

93. The generating stations of NEA and independent power producers (IPPs) must demonstrate a high level of safety and technological standards before being grid connected. However, MHPs are often designed as isolated systems to supply electricity mainly for lighting purposes. They have many inherent safety issues that are a concern for the NEA. For example, most MHPs use wooden poles, which have a shorter life span. Also, the use of electronic load controller (ELC) in MHPs (compared to governors in NEA's generating stations) deteriorates the power quality of these plants. To be grid connected MHPs need to meet the grid's technical standards, which includes an "NEA quality" distribution system.

94. There is a need for the APEC to demonstrate safety standards of MHPs to NEA personnel from various internal departments, such as transmission, distribution, technical services, system planning and finance (see Box 1). The recent decision by the NEA to buy power from MHPs at the same FIT as IPPs indicates that MHPs would also be treated similar to IPPs. Currently, a generation license is not required for hydropower plants up to 1000 kW capacity to facilitate simpler implementation of the MHP. However, not requiring licenses has resulted in unclear

FIGURE 9: Prediction of MHP capacity (kW) that will be added till 2020



designation of water rights and has sometimes led to conflicts (e.g. diversion of river flows upstream of an existing MHP for irrigation).

95. An increase in the subsidy amount (total amount, amount per household and per kW) has resulted in an increase in both the number of power plants and the aggregate installed capacity. Change in each subsidy policy in 2000, 2006 and 2009, also increased the average plant size as mentioned before.

96. The establishment of the AEPC has significantly accelerated the growth of the micro hydropower sector. A central government body responsible for the promotion of MHP along with donor support has resulted in funds being available for subsidy. Furthermore, the AEPC has also made available various support mechanisms, such as technical design, construction support and monitoring of MHPs. The private sector has also been strengthened due to participation in design, manufacturing of equipment and site construction/installation. It takes about two years for the subsidy to make a visible impact on installed capacity. This implies that MHPs should be built in about two years' time from the start of subsidy disbursements.

03

Scaling Up Potential of Micro Hydropower in Nepal

98. The AEPC currently faces two contrasting problems in scaling up of MHPs. On the one hand, there is a growing demand for MHPs from more communities; and on the other hand there is an increasing threat to investors from the grid being extended into existing or even under-construction MHP sites. Thus, even as the AEPC tries to meet the growing demand for MHPs by scaling up its initiatives, it has to find means for protecting prior investments made in MHPs that are under threat from grid extension. Connecting such MHPs to the grid is the only alternative to abandoning them.

99. Until recently, the NEA was reluctant to connect any MHP that was less than 100 kW in capacity. From NEA's perspective, an MHP with low installed capacity was considered not worth connecting to the grid as the power and energy from such plants would be low compared to the efforts required in managing them (e.g. meter reading, dispatching monthly payment and monitoring quality issues). The AEPC had responded to this issue by interlinking smaller MHPs (where larger MHPs do not exist) to form a mini-grid of at least 100 kW in capacity. Therefore, the Baglung Mini-Grid was formed such that the aggregate installed capacity is 107 kW (6 MHPs were interlinked). However, as discussed earlier, recent developments indicate that MHPs less than 100 kW are permitted to be grid connected, provided that they meet NEA's technical (and safety) requirements.

100. Thus, the AEPC has three key system configurations to address for scaling up MHPs in a sustainable manner. These are:

- MHP as a standalone and off-grid system;
- Mini-grid system of MHPs that could eventually be connected to the grid;
- MHP as a grid connected system.

101. This chapter analyzes the merits of pursuing each of the systems by examining their technical, financial, economic and institutional performance. The objectives of this chapter are presented in Section 3.1. Section 3.2 discusses the framework for selecting the pathways for scaling up MHPs. Sections 3.3, 3.4 and 3.5 assess various aspects of scaling up MHPs as a standalone system, MHPs as a mini-grid system, and MHPs as a grid connected system, respectively. Based on the findings in these sub-sections, major issues are discussed and appropriate suggestions to address these issues are presented in Chapter 4.

3.1. OBJECTIVES OF THE CHAPTER

102. The objectives of this chapter are to analyze how MHPs can be scaled up sustainably when:

- they operate as standalone systems;
- deficit of one or more MHPs can be compensated by other MHPs in the vicinity that have surplus power through a mini-grid system; and
- the grid arrives in the vicinity of the plants.

3.2. FRAMEWORK FOR ASSESSING PERFORMANCE

103. The key research questions that would guide the analysis are as follows:

- Should MHPs be scaled up as standalone, off-grid solutions to enhance the access of rural communities to electricity?
- Should MHPs be connected to the national grid either as individual MHPs or as a mini-grid of interconnected MHPs?
- Should MHPs be interconnected to form off-grid mini-grids to better serve the community?

TABLE 9: | Framework questions for analyzing feasibility of standalone MHPs, mini-grids and MHP–grid connection

MHP configuration	Technical	Financial	Economic	Institutional
Standalone MHP	Are MHPs technically reliable? Are they capable of meeting local demand consistently?	Are MHPs financially viable? Is there adequate quantum and rate of return to investors?	Are societal investments (subsidy) in MHPs commensurate with economic welfare delivered by them?	Is the current institutional architecture and capacity adequate to manage MHPs?
Mini-grid	Are MHP–mini-grids technically reliable? Do they lead to better plant load factors (PLFs) for the constituent plants? Can they serve the local demand better than as standalone plants? Does higher overall plant capacity lead to serving more commercial demand?	Is the incremental revenue (increased PLF and increased commercial loads) from interconnecting MHPs adequate to cover incremental investments?	Does the incremental economic welfare due to interconnection of MHPs into a mini-grid warrant a higher subsidy if the financial viability is not attractive?	Can MHP Functional Groups make the transition to larger and more formal institutions?
Grid-connected MHP	Can MHPs (as standalone or as mini-grids) be connected safely to the national grid? Will it make both the MHP and the national grid (NEA) more reliable or unreliable? Overall, will the MHPs be net suppliers of electricity or net importers from the grid? Will this improve the PLFs of the MHPs? Will this lead to development of commercial and productive loads?	Do the incremental revenues from connecting to the grid justify the investments? Who should make the investments? What are the financial implications for the NEA, the MHP Functional Groups and the community at large?	Does the incremental economic welfare delivered by connecting the MHP to the grid justify the costs? How does this compare with the economic welfare delivered by just extending the grid without connecting to the MHP generator?	What are the institutional forms needed to manage a grid connected, generation and distribution system? What support is needed to the community and service providers? What institutional mechanisms are needed for the AEPC and the NEA to work together to support this?

104. For each of these research questions, if the answer is "yes", then the study after taking into account the challenges and opportunities will propose a roadmap for moving ahead. More specifically, in order to address the research questions, framework questions addressed in this chapter are presented in Table 9.

3.3 STANDALONE MHPS

105. As mentioned earlier, standalone MHPs serve communities well in the absence of the national grid. With the subsidy and technical support provided by the GoN (through AEPC), the numbers of isolated MHPs are steadily growing. This alone indicates that there is: (a) a demand in non-electrified rural communities for MHPs, and (b) with subsidy support, communities are able to afford such MHPs. The majority of MHPs are functioning well beyond their economic life (15 years as per AEPC guidelines), which indicates that the technology has become sustainable. While communities have not been able to recover capital costs, they are able to meet the operation and maintenance costs.

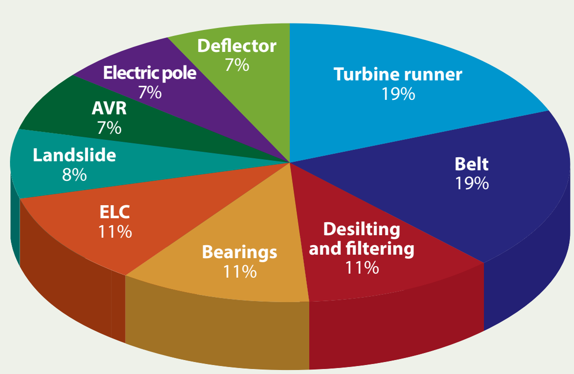
3.3.1. TECHNICAL RELIABILITY

106. Isolated standalone MHPs were found to be doing well except for a few minor technical problems. The most frequent technical problems discovered during the site survey were turbine runner damage due to silt abrasion, bearing rupture, ELC breakdown, and belt damage (Figure 10).

107. Silt problems arise from bad design and construction of the settling (desilting) basin. A settling basin must be designed to lower the velocity of water by providing a large basin surface area such that abrasive silt particles can settle. The length and width of the basin must be large enough to trap all silt particles greater than a certain size, which varies from 0.2 mm to 0.5 mm depending upon the head and type of turbine of the scheme. The dimensions of the basin must be calculated based on the ideal settling basin concept to minimize turbulence effect. Additionally, the basin should be able to store the settled silt particles for a certain number of hours because MHPs are not designed for continuous flushing. The settled silt particles then need to be removed from the basin by opening gates or valves and flushing the sediment using the incoming flow. To achieve satisfactory flushing, the bed gradient of the basin must be designed to be steep enough to create velocities capable of removing all the sediment during flushing.

108. However, due to scarcity of funds (and sometimes space), communities often tend to decrease the dimensions of the basin, which results in silt particles not settling down. Eventually, such silt particles find their way to the turbine runner blades and damage them by their abrasive action. Therefore, by designing appropriately dimensioned settling basins and following the design during construction, two most frequent problems in technical reliability can be avoided. The AEPC has prepared various technical guidelines that address such design issues.

Figure 10: Technical problems seen during MHP site survey



109. Belt and bearings damages occur due to misalignment of the turbine-generator set. This problem can be avoided by aligning the sets precisely and by exclusively monitoring this process. Also, using a high quality belt and bearings can help prevent these issues.

110. The ELC diverts unused electrical power to ballasts (heaters) so that the frequency of the generator can be kept constant. ELC is a home-grown electronic technology manufactured in Nepal according to international design. ELCs are found to be highly susceptible to fault currents caused by lightening or short circuits. ELC breakdown can be avoided by using high quality lightening/surge arrestors to protect from fault currents. Further research is being undertaken by various ELC manufacturers to combat his problem.

111. These minor problems can be avoided to a large measure by taking precautions, building a robust design and its faithful implementation. If these measures are taken, technical reliability of MHPs will be very high.

3.3.2. ABILITY TO MEET POWER NEEDS

112. Most of the MHPs met the lighting power needs of households adequately in their service area. However, most also were found to have a power deficit during the peak hours. The subsidy for MHPs is provided on the basis of 100–200 W/household. Due to increase in household demand (500–800 W rice cookers) and commercial use (7.5 kW agro-processing motors) of electricity, this 100–200 W/household ceiling for subsidy is becoming inadequate. This is resulting in load-shedding during peak hours and eventually, most MHPs will suffer from this problem as the demand for electrical energy increases and the installed capacity of MHPs remain constant. A better alternative is to switch to a supply based subsidy and

TABLE 10 | Financial analysis assumptions for standalone MHPs

Parameter	Estimated value used in financial analysis	Remarks
Plant size in kW	20 kW, 50 kW, 100 kW	Based on MHPs installed during January 1, 2012 to December 31, 2013
Life of the plant in years	15 years	
Capital cost of the plant	NPR* 450,000/kW for 20 kW; NPR 425,000/kW for 50 kW; NPR 400,000/kW for 100 kW	Based on MHPs installed during January 1, 2012 to December 31, 2013
Financing mix, including debt	50 percent subsidy, 40 percent equity, 10 percent loans	Based on analysis of MHP financing and site survey. Around 10 percent of the capital cost is on average contributed by the community in kind
Component-wise capital cost	53 percent electro-mechanical, 20 percent civil structures, 27 percent others.	Based on "Micro-Hydropower In Nepal: Enhancing Prospects For Long-Term Sustainability", Alex Arter, September, 2011
Loads: domestic and commercial	Domestic: 18 kWh/HH/month[13] Commercial: 4–5 kWh/HH/month[14]	Site survey
Plant load factor	24 percent	Derived from site survey results
Tariff	NPR 6/kWh-domestic and NPR 8/kWh-commercial	Derived from site survey
Operations and maintenance cost	2 percent of total capex annually	
Salary and administrative cost	NPR 12,000 for two operators and NPR 10,000 for MHP manager. Total NPR 22,000/month	Site survey
Depreciation	7 percent on straight line basis on 73 percent of capex	
Tenor and terms of loan	14 percent rate of interest, 7 years term	Site survey

*NPR 1 = US$0.0104; HH = household

have a demand side ceiling of 500–1000 W/household or energy-based metered systems with subsidy to utilize the maximum capacity possible.

3.3.3. FINANCIAL VIABILITY

113. To determine financial performance of standalone MHPs the parameters listed in Table 10 below were estimated based on data collected during site visits and from several published reports.

3.3.3.1. Plant size

114. By definition MHPs range in capacity from 10 kW to 100 kW. Table 11 shows the details of the plants covered in the site visits.

115. As can be seen from the table, the site visit focused on larger capacity MHPs. This is because at the start of this study, the NEA was willing to connect only MHPs of 100 kW or larger capacity to its grid.

116. On an average every kW of installed capacity serves eight households, which implies that when all households are drawing power from the MHP simultaneously, each household can connect up to a maximum of 125 W. An analysis of the MHPs installed in Nepal[15] from January 1, 2012 to December 31, 2013 (a period of two years) is shown in Figure 11.

117. Figure 11 shows that the proportion of plants of the three size categories of MHPs is similar. Accordingly, for carrying out a financial performance analysis of MHPs, standard plants of 20 kW, 50 kW and 100 kW were considered.

[13] Calculated from an average usage of 120 W/HH operating 6 hours a day, 300 days in a year works out to 18 kWh/HH/month

[14] Commercial loads in closed communities are linked to the households in the area who would be the users of such commercial services. Hence commercial loads have been expressed as kWh/HH rather than as kWh/commercial user.

[15] Source: AEPC

3.3.3.2. Plant life

118. Although there are several plants that are still operational 20–30 years after they were first commissioned, the general norm is to consider the life span of an MHP to be 15 years and the same has been assumed in this financial analysis. Fifteen years would be too short a time for conventional larger sized power plants to be connected to the grid and operated commercially, but for MHPs this is not possible because of the following:

- The quality of civil structures is such that they may not function well beyond 15 years.
- Due to wear and tear, the turbine runners generally do not last beyond 15 years.
- The uncertainty of the arrival of the grid does not offer any advantages in designing MHPs for an extended economic life. The main issue is to seek opportunities to ensure that the MHPs are used until their economic lives are exhausted, such as by connecting to the grid.

3.3.3.3. Capital cost and financing mix of the MHP

119. The capital cost of the MHP is dependent mainly on the head, the flow, the type of turbine, the length of the penstock and accessibility (remoteness of location). Table 12 shows the capital cost and financing mix of the MHPs in the sites visited:

120. Overall the local community monetarily contributes nearly 50 percent (40 percent community contribution[16]+10 percent loans), while the rest comes from the AEPC and other sources (VDC, DDC) as capital subsidy. The average installed cost/kW ranges from NPR 400,000 for a 100 kW MHP to NPR 450,000/kW for a 20 kW MHP. The average cost/household is NPR 40,000 of which nearly a half comes from the local community itself, i.e. NPR 20,000/household. Loans comprise a mere 10 percent of the total finance mix which can be due to lack of access to loans or the ability of the communities to meet most of the non-subsidized cost of micro hydropower project implementation. The data from the AEPC on the last 58 plants that were supported with additional financing in 2013–14 (see Figure 12) indicate that the communities had lack of access to credit.

121. Thus, the financing mix used in the financial analysis is 50 percent subsidy, 40 percent equity (local community contribution in cash and kind) and 10 percent loans.

3.3.3.4. Component-wise Capital Cost

122. Capital cost of a typical MHP (see Figure 13[17]) comprises electro-mechanical components (53 per-

TABLE 11 | MHP sites visited and their plant size

Name of MHP	Location	District	kW	HH served	kW/HH	Commercial connections
Gottikhel MHP	Gottikhel	Lalitpur	16	80	5	10
Midim Kholan MHP	Ishaneshwor	Lamjung	83	NA	NA	NA
Bhujung MHP	Bhujung	Lamjung	64	365	6	14
Ghandruk I MHP	Ghandruk	Kaski	50	221	4	14
Ghandruk II/Bhirgyu MHP	Ghandruk	Kaski	50	289	6	29
Daram Khola I MHP	Wamitaxar	Gulmi	135	1,400	10	32
Daram Khola II MHP	Wamitaxar	Gulmi	85	900	11	19
Giringdi Kholan MHP	Kharbang	Baglung	85	838	10	34
Malekhu I MHP	Mahadevsthan	Dhading	26	300	12	6
Malekhu II MHP	Mahadevsthan	Dhading	18	118	7	5
Yafre MHP	Yafre	Taplejung	112	870	8	5
Total			**724**	**5,461**	**8**	**168**

HH = household
Source: Site Survey 2014

[16] This includes sweat equity and cash equity from the community

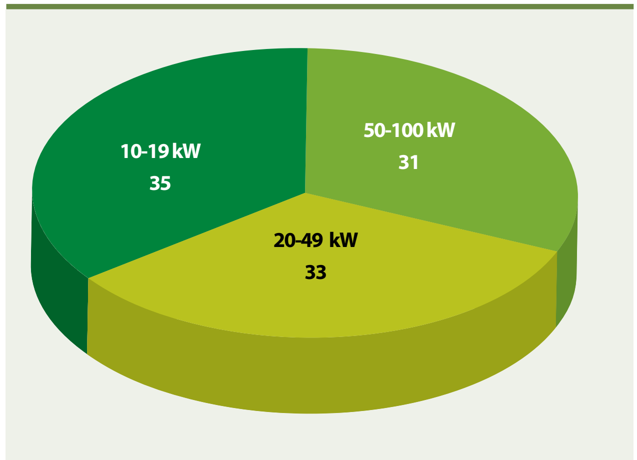
[17] Reproduced from "Micro-Hydropower In Nepal: Enhancing Prospects For Long-Term Sustainability", Alex Arter, September, 2011

cent), a civil component (20 percent) and others (27 percent), which includes overheads and transportation. Thus, for the purposes of calculating depreciation, 73 percent of the capital cost will be treated as an asset block. A straight-line depreciation over the life of the plant has been considered. This results in the depreciation of approximately 7 percent per year for a plant life of 15 years.

3.3.3.5. Loads: Domestic and Commercial

123. MHPs are primarily designed for delivering electricity (lighting) to households. Usually, MHPs are sized to deliver between 100–200 W/household subject to resource (head and flow of water) availability. As presented above, 1.0 kW caters to about eight households (average load of 125 W/household). A typical MHP-connected household uses electricity for about 5–6 hours in a day. Thus, the average consumption is in the range of 18–22 kWh/household/month.[18] The project design document (PDD) of the registered clean development mechanism (CDM) project on MHPs by the AEPC also mentions that the average kWh of electricity consumed/household/month in rural Nepal is 18 kWh. Thus, the financial analysis uses 18 kWh/household/month as the level of electricity use.

Figure 11: Size-wise number of plants installed during Jan 1, 2012–Dec 31, 2013



124. Commercial loads (also referred to as loads from productive end-uses) vary from place to place. Table 13 shows the types and number of productive end-uses found in the sites visited during this study.

125. The most common productive end-uses are agro-processing units[19] followed by poultry farms. Hotels are the common productive end-uses in areas of tourist interest, such as Ghandruk and Bhu-

TABLE 12 | Capex and financing mix of MHP sites visited

Name of MHP	Cost Structure (NPR*)					
	Total Cost	Subsidy (AEPC)	Subsidy (Others)		Community	Loans
Gottikhel MHP		2,277,000	0	385,000	0	1,892,000
Midim Kholan MHP		34,900,000	16,700,000	0	16,000,000	2,200,000
Bhujung MHP		11,934,623	0	11,934,623	Labor contribution	NA
Ghandruk I MHP		3,400,000	0	2,100,000	400,000	900,000
Ghandruk II/Bhirgyu MHP		15,000,000	4,600,000	1,100,000	4,800,000	4,500,000
Daram Khola I MHP		59,000,000	14,500,000	0	40,500,000	4,000,000
Daram Khola II MHP		20,500,000	4,900,000	10,600,000	0	5,000,000
Giringdi Kholan MHP		22,341,000	6,375,000	2,166,000	12,100,000	1,700,000
Malekhu I MHP		4,414,711	NA	NA	NA	NA
Malekhu II MHP		4,314,977	NA	NA	NA	NA
Yafre MHP		40,000,000	14,400,000	6,450,000	14,315,000	0
Total	218,082,311	61,475,000		34,735,623	88,115,000	20,192,000
Average finance mix**	100 percent	28 percent		16 percent	40 percent	9 percent

*NPR 1 = US$0.0104.
**Since data from some installations are missing, the sum of subsidies, community contribution and loan will not add up to 100%.
Source: Site Survey, 2014.

[18] "Power And People: The Benefits Of Renewable Energy In Nepal", Sudeshna Banerjee, Avjeet Singh, Hussain Samad, World Bank May 2010
[19] An agro-processing unit comprises a rice huller and a flour mill run by a 10 hp (7.5 kW) electric motor.

Figure 12: Source of total capex in 58 MHPs supported by AEPC

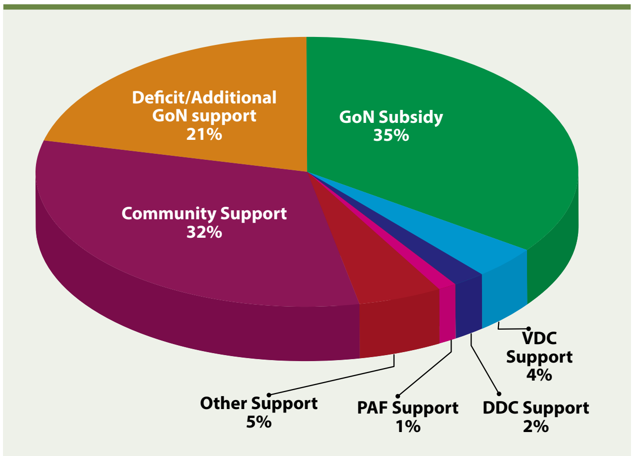
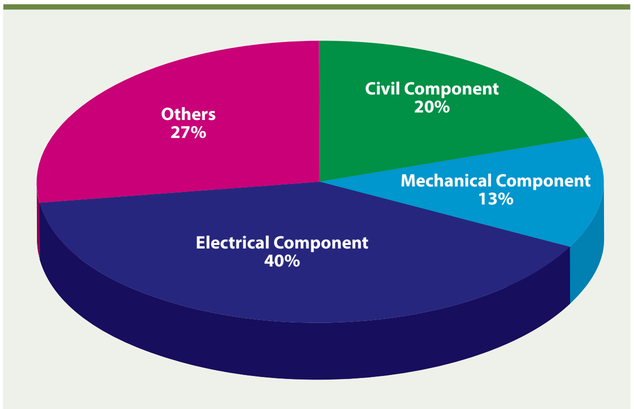


Figure 13: Component wise capital cost of MHP



jung, which form a part of the Annapurna trekking circuit. On average a single agro-processing unit exists for every 100–120 households. Furthermore, larger plants tend to have a greater number of productive end-uses. A typical agro-processing unit would have a 10 hp (7.5kW) electric motor that is used for about 2–3 hours/day for approximately 20 days in a month serving about 100–120 households. Similarly, a sawmill has a 5–7.5 kW electric motor that is used for an average of 2–3 hours/day for 20 days in a month. A typical poultry farm has a 500–750 W connection that is used for about 8–10 hours/day for 20 days in a month.[20] Table 14 presents the quantity of electricity consumed in the domestic sector and the commercial sector for the sites visited during the survey.[21]

126. The proportion of kWh consumed by domestic and commercial customers is shown in Figure 14.

127. On average, 80 percent of the kWh is consumed in an MHP in the domestic sector, mainly for lighting, and 20 percent for productive end-uses. This results in about 4–5 kWh of commercial loads/household/month. The CDM-PDD for MHP by the AEPC presents an estimate of 9 kWh/household/month for commercial applications. However, for the purpose of financial analysis in this study, commercial use of energy at 4 kWh/household/month has been used.

3.3.3.6. Plant load factor

128. Based on domestic and commercial consumptions estimated in the preceding chapter, the estimated PLF for the plants surveyed are as presented in Table 15.

129. However, these plants are well established and located in areas of high commercial transactions, such as market centers (Daram Khola II and Giringdi Khola) and tourist areas (Ghandruk I & II and Bhujung). An MHP study[22] has pegged the PLF for MHPs at 18 percent while a World Bank study[23] has mentioned 33 percent as the average PLF. This study uses a PLF of about 24 percent based on the estimates of domestic and commercial uses discussed in the preceding chapters.

3.3.3.7. Tariff

130. Both power and kWh based tariffs were found in the MHPs visited. Table 16 provides details on tariffs in the MHP sites surveyed.

131. On average a power-based tariff of NPR 100/100 W/month is equivalent to a kWh-based tariff of NPR 5.5. Domestic tariff has been taken at NPR 6/kWh for carrying out the financial analysis. Commercial tariff has been estimated at NPR 8/kWh.

3.3.3.8. Operations and maintenance costs

132. The main operations and maintenance costs are related to repairs for the ELC, runner blades, intake channels and replacement of wooden electric

20 A minimum time gap is needed between two batches of broilers in the same poultry shed to allow for carrying out appropriate cleaning, disinfection operations and preparing the litter bed for releasing the next batch of Day Old Chicks (DOC).

21 The monthly consumption of kWh of electricity for domestic and commercial use has been estimated based on primary survey data

22 "Micro-Hydropower In Nepal: Enhancing Prospects For Long-Term Sustainability", Alex Arter, September, 2011.

23 Power And People: The Benefits of Renewable Energy In Nepal, Sudeshna Banerjee, Avjeet Singh, Hussain Samad, World Bank May 2010, Page 13.

TABLE 13 | Productive end-uses of MHP sites visited

	Gottikhel	Midim Khola	Bhujung	Ghandruk I	Ghandruk II	Daram Khola I	Daram Khola II	Giringdi Khola	Malekhu I	Malekhu II	Yafre	Total
Agro-processing	4	0	3	0	0	13	9	8	1	2	2	42
Poultry	0	0	2	0	0	10	0	15	4	0	3	34
Hotels	0	0	0	13	18	0	0	0	0	0	0	31
Sawmill	0	0	3	0	0	2	3	4	1	1	0	14
Grill/Welding shop	1	0	0	0	0	0	3	3	0	0	0	7
Crusher	0	0	0	0	0	1	0	0	0	0	0	1
Telecom tower	0	0	1	1	0	3	0	0	0	0	0	5
Ropeway	0	0	3	0	0	0	0	0	0	0	0	3
Small industries (Lokta/Chowmein/Soap)	0	0	0	0	3	2	3	3	0	0	0	11
Irrigation	0	0	0	0	0	0	0	0	0	1	0	1
Photocopier/Computer center	1	0	0	0	1	1	1	1	0	1	0	6
Others	4	0	2	0	7	0	0	0	0	0	0	13
Total	10	0	14	14	29	32	19	34	6	5	5	168

Source: Site Survey, 2014

TABLE 14 | Domestic and commercial electricity consumption (kWh) for MHP sites visited

Name of MHP	Household	Productive end-uses			kWh consumed/month	
		Agro-processing	Poultry	Others[24]	Domestic	Commercial
Bhujung MHP	365	3	2	9	6,570	1,325
Ghandruk I MHP	221	0	0	14	3,978	6,840
Ghandruk II/Bhirgyu MHP	289	0	0	29	5,202	6,480
Daram Khola I MHP	1,400	13	10	9	25,200	2,550
Daram Khola II MHP	900	9	0	10	16,200	2,250
Giringdi Kholan MHP	838	8	9	17	15,084	3,818
Malekhu I MHP	300	1	4	1	5,400	390
Malekhu II MHP	118	2	0	3	2,124	300
Yafre MHP	870	2	3	0	15,660	480
Total	**5,301**	**38**	**28**	**102**	**95,418**	**24,433**

poles. These are estimated at 2 percent of the total capital cost of the MHP on an annual basis.

3.3.3.9. Salary cost

133. Typically, an MHP that operates for more than 10 hours per day employs two operators (NPR 6000/month each) and a manager (NPR 10,000/month) totaling a cost of NPR 22,000/month. A shift is usually 10–12 hours in duration.

3.3.3.10. Financial analysis

134. Based on the above parameters, financial analysis has been carried out for 100 kW, 50 kW and 20 kW MHPs with and without capital subsidy covering profit/loss statement, cash flow analysis, estimation of internal rate of return (IRR), net present value (NPV) and the levelized unit cost of electricity (LUCE). The details of the financial analysis can be found in Annex 4 and the summary of the results is presented in Table 17.

[24] Includes other productive end-uses such as sawmills, grill works, etc.

TABLE 15 | Estimation of PLF of MHP sites visited

Name of MHP	kWh consumed / year	PLF
Bhujung MHP	94,740	17%
Ghandruk I MHP	129,816	30%
Ghandruk II/Bhirgyu MHP	140,184	32%
Daram Khola I MHP	333,000	28%
Daram Khola II MHP	221,400	30%
Giringdi Kholan MHP	226,824	30%
Malekhu I MHP	69,480	31%
Malekhu II MHP	29,088	18%
Yafre MHP	193,680	20%
Average PLF		26%

135. Results of a break-even analysis carried out for a 100 kW MHP is presented in the Table 18.

136. Similarly, a break-even analysis was carried out for a 50 kW and a 20 kW MHP, and the results for all three capacities considered are presented in Figure 15.

3.3.3.11. Observations on Financial Analysis of Standalone MHPs

137. From a conventional financial analysis viewpoint, the profitability of MHPs is poor, with or without subsidy. Smaller plants in the range of 20–50 kW are not able to cover interest on loans and have a negative return on their investment. Plants with capacity of 100 kW are relatively more profitable as they are able to cover all their operation and maintenance costs, salaries and also pay interest on loans. However, even in their case the return on investment (RoI) is less than 1 percent.

138. The LUCE[25] including a 16 percent return on equity (RoE) is higher for smaller plants and in all cases much higher than the tariff being charged. This implies that tariffs are not taking into account the full cost and a reasonable RoE. In fact in the Bhujung MHP, the community recently decided to lower the tariff from NPR 100/100 W/month to NPR 65/100 W/month after the loan portion was paid off.

139. Tariffs are set to just recover the operating costs and sometimes even just the salary costs. To meet the costs of major repairs, users are asked to contribute additional sums. The tariffs are also lower because after having contributed in cash and/or kind for the construction of the MHPs, the communities are unwilling to pay higher tariffs reflecting the real costs (see Box 2).

140. Thus, MHPs are run to recover operating costs only, with capital investments (local community contribution) being treated as sunk costs. This leaves them financially vulnerable when they have to meet the costs of major repairs or even pay better salaries to their staff. Since it takes time to mobilize money from users to pay for maintenance and repairs, it gets postponed eventually leading to degradation of the assets, and loss of production and revenue. This further compounds the poor financial health of the MHPs.

141. This mindset of only meeting operating costs and the lack of pressure to deliver a RoE, leads to a dearth of interest in increasing loads during off-peak hours. It also means that such MHPs would not be interested in taking loans since it would increase their operating costs and they would be forced to increase their revenue base by increasing off-peak loads. Such MHPs are therefore not attractive to banks and financial institutions.

142. Given this situation, standalone MHPs seem to be run more as social enterprises that deliver a social good than as business enterprises. This orientation has been further accentuated by changes in the subsidy policy that favor community-managed MHPs instead of entrepreneur-managed ones. This to some extent explains the low load development in MHPs (especially off-peak loads which are largely productive end-uses) and the lack of interest in financial institutions to finance them.

143. Thus, MHPs today are financed by a mix of capital subsidy and equity (sweat and cash). Communities that are able to mobilize their share of the capex (NPR 20,000/household) are able to set up an MHP and those that are less affluent simply cannot afford to do so. With many sites in the hilly

25 Levelized Unit Cost of Electricity is the ratio of discounted operating cost+ capex to discounted number of kWh generated over the lifetime of an MHP.

regions of Western and Central zones of Nepal[26] getting slowly saturated with MHPs and with the grid also making inroads,[27] the potential sites for MHPs are now more in the poverty stricken far-west. This is one of the major challenges of scaling up MHPs in Nepal.

3.3.4. ECONOMIC ANALYSIS

144. In the preceding sections, the financial performance of MHPs has been analyzed from the point of view of the MHP as a business unit. In this section, the economic performance of MHPs is analyzed from the perspective of the society or economy at large. While in the preceding sections, the revenue generated from sale of electricity was set off against the costs of generating electricity, in an economic analysis, the benefits that accrue to society (in this case users/customers) would be set off against economic costs of generating electricity. A number of previous studies have estimated the economic benefits that accrue from electrification, and the findings from these studies have been taken into account in the analysis here.[28] In estimating economic benefits and costs,[29] all financial costs are taken net of taxes, without subsidies, and the labor wage rate of NPR 500/day is deflated to the minimum wage rate for unskilled labor of NPR 318/day.[30]

3.3.4.1. Estimation of economic costs

145. The costs of setting up and running an MHP include only the capital cost and the operations and maintenance costs. Salaries are not a relevant economic cost because they also feature as economic benefits of an MHP and thus cancel out each other. Table 19 presents the economic costs for a notional 20 kW, 50 kW and 100 kW MHP.

3.3.4.2. Estimation of economic benefits

146. Several studies on the economic benefits delivered by MHPs have been conducted in Nepal. These include: increased welfare enjoyed by households due to a shift from traditional (kerosene) lighting to electric lighting, increased knowledge from ac-

Figure 14: Proportion of KWh consumed in domestic and commercial sectors

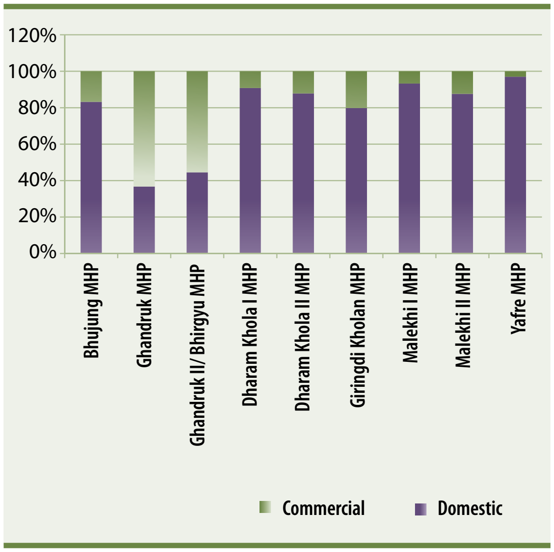
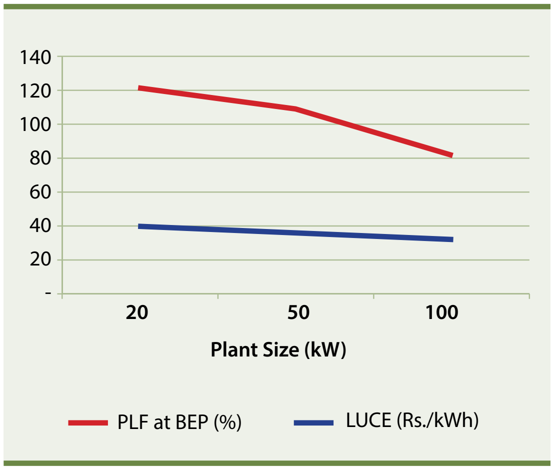


Figure 15: Break-even PLF and LUCE for standalone MHPs



cess to television and radio, higher incomes from increased productivity, improved health and educational outcomes. A study that used a multiple linear regression model attributed an average annual increase in household income of US$121 (about 8 percent of the average annual income) to electricity access alone.[31] However, while there is a correlation between higher income and access to electricity through MHPs, the direction of causality is not clear-

[26] These are the relatively more prosperous areas in rural Nepal hills mainly on account of employment in the Indian and British army and remittances from migrant workers. Steady remittance has ensured greater prosperity for this area.
[27] The opening of the mid-hills road is increasing the spread of grid in the hills of Nepal
[28] IEG/World Bank (2008), World Bank (2011), UNDP (2011).
[29] This is the approach taken throughout this study for estimating economic costs
[30] The daily minimum wage of NPR 318 was established in the Government of Nepal's Gazette (Jeth 27, 2070).
[31] UNDP (2011)

TABLE 16 | Details of tariff in MHP sites visited

Name of MHP	Tariff/month	
	Domestic	Commercial
Bhujung MHP	NPR* 65/100 W	NPR 8.00/kWh
Ghandruk I MHP	NPR 1.5/W/month	NPR 2/W/month
Ghandruk II/Bhirgyu MHP	NPR 150/100 W	NPR 200/100 Watts
Daram Khola I MHP	NPR 100/20 kWh + NPR 10/ kWh	NPR 1,500/190 kWh + NPR 10/kWh
Daram Khola II MHP	NPR 100, 150, 300/20 kWh (0.5, 2, 5 A) + NPR 10/kWh	NPR 1,500/190 kWh + NPR 8/kWh
Giringdi Kholan MHP	NPR 60, 100, 150/10, 15, 20 kWh/month (0.5A, 1.0A, 3.0A) + NPR 7/kWh	NPR 800/100 kWh/month (6.0A) + NPR 8/kWh
Malekhu I MHP	NPR 80/20 kWh + NPR 7/kWh	NPR 7/kWh
Malekhu II MHP	NPR 70/ 20 kWh + NPR 5/kWh	NPR 7/kWh
Yafre MHP	NPR 100/connection + NPR 8/kWh	NPR 100/connection + NPR 10/kWh

*NPR 1 = US$0.0104; A = Ampere

TABLE 17 | Summary of financial analysis of standalone MHPs

Plant size	100 kW		50 kW		20 kW	
Parameter	With subsidy	Without subsidy	With subsidy	Without subsidy	With subsidy	Without subsidy
FIRR	Cannot be calculated due to large number of negative net cash flows					
NPV (NPR* million)	-21.62	-46.7	-13.68	-27	-8.02	-13.66
LUCE (NPR/kWh)	32.73	58.9	36.3	64.11	39.15	72.57
Profitability	Covers O&M, interest on loans and salaries.		Covers O&M, and salaries but not able to service the loan.		Barely covers salary costs alone	

*NPR 1 = US$0.0104; O&M = operation and maintenance

TABLE 18 | Results of break-even analysis for 100 kW MHP

Parameter	With Subsidy	Without subsidy
Total fixed cost (NPR*)	1,802,200.00	3,340,400.00
Total variable cost (NPR/kWh)	3.83	3.83
Sale price (NPR/kWh)	6.34	6.34
Break-even Point (kWh)	717,034	1,329,031
Break-even Point (NPR)	4,549,456.10	8,432,473.17
Sales (kWh)	208,800	208,800
Increase in sales needed to reach BEP (kWh)	508,234	1,120,231
PLF at BEP	82%	152%
Current PLF	24%	24%

*NPR 1 = US$0.0104

ly established. For example, it is not clear if higher income households and VDCs gain access to MHPs (community has to make significant investments to set up an MHP) or if access to electricity results in higher income. Another study produced econometric estimates of 11 percent increase in non-farm income from electrification through micro hydropower; however, the gain in total income (farm plus non-farm) was not found to be statistically significant.[32] This is consistent with the observation that MHP electricity is primarily used by households for lighting, and therefore may not have a substantial impact on economic outcomes.

147. Therefore, in this study, consumer surplus from access to better lighting has been taken as the lower bound of economic benefits from an MHP and all other economic benefits have not been accounted for. Thus, the economic benefits are a conservative estimate. As seen in the preceding section productive end-use customers accounted for about 20 percent of all units consumed. Typically, electricity from an MHP replaces use of diesel in these units. Thus, economic benefits enjoyed by these users are directly related to savings from avoided cost of running a diesel engine. Finally, since electricity from MHP is carbon-free, economic benefits arise in the form of revenue from sale of certified emissions reductions (CERs) that stem from replacement of kerosene (for lighting) and diesel (for productive end-uses).

3.3.4.3. Lighting benefits for households

148. Households use electricity from MHPs primarily for lighting, replacing the use of kerosene. The price of kerosene is NPR 105.5/liter and a household in rural Nepal consumes about 3 liters of kerosene every month. One study[33] showed that nearly 90 percent of the kerosene usage gets replaced in households that are connected to MHP power supply. Thus, one MHP-connected household saves NPR 285/month in expenditures on kerosene, while it spends about NPR 108/month (18 kWh x NPR 6/kWh) on electricity. In this scenario, the overall cash savings for a household/month is NPR 177. Another study indicated that household savings in lighting due to electrification was about US$22 per annum, or approximately NPR 177 per month.[34]

149. However, using the change in household expenditure for lighting as a measure of the benefit of rural electrification underestimates the true eco-

Box 2: RELEVANCE OF CONVENTIONAL FINANCIAL ANALYSIS FOR COMMUNITY OWNED ASSETS

Tariffs for use of community owned and operated assets are usually set at only recovering operating costs, primarily cash costs. They hardly ever take into account depreciation (a typical non-cash operating cost) or factor in a RoE.

When faced with a major repair, however, the community contributes in cash and/or kind. This may be treated as drawing from the depreciation fund, which has been lying in a distributed form with the community. This is how irrigation schemes, rural roads, temples and schools are managed.

Communities in Nepal manage MHPs in a similar manner. Conventional financial analysis that includes non-cash costs and factors in a RoE fails to appreciate this method of tariff setting and management, and therefore deems MHPs as financially unviable.

On the contrary, the fact that community owned and managed MHPs have been in operation for a long period of time indicates the need to accept that these may not be amenable to conventional bank finance, but are nevertheless operationally viable.

32 World Bank (2011)

33 Ibid.

34 UNDP (2011)

TABLE 19 | Estimation of economic costs of standalone MHPs

Parameter	Financial Cost			Economic Cost		
	20 kW	50 kW	100 kW	20 kW	50 kW	100 kW
Capital costs/kW (NPR*/kW)	450,000	425,000	400,000	389,802	368,146	346,491
Operation and Maintenance costs/kW (NPR/year)	9,000	8,500	8,000	7,796	7,363	6,930

*NPR 1 = US$0.0104;

Note: 53 percent of capex is electro-mechanical, which attracts 13 percent VAT, and 20 percent of capex is labor; 2 percent of financial capex, less VAT, is taken as annual repairs and maintenance costs.

nomic benefit because it only accounts for the financial savings delivered, whereas the quantum of lighting provided by electric lights is far greater than that provided by kerosene for the same amount of expenditure. Therefore, if MHP households gain by reduced expenses on lighting (e.g. NPR 31.65 for kerosene plus NPR 108 for electric lighting compared to NPR 316.5 for kerosene alone), more significantly, they also gain by getting a far better quantum of lighting measured in kilo-lumen-hours (kLh) for a lower price. Table 20 provides details of price/kLh and quantity of kLh consumed for kerosene users and 20 kW MHP users.

150. The MHP consumer clearly gets a source of energy that is cheaper and provides better lighting and yet pays far less than what it would have cost them, if they used kerosene. Based on the two price points and consumption points for kerosene and electricity-based lighting, a constant elasticity (log linear) demand curve is derived, and the consumer surplus calculated from this functional form amounts to NPR 1,414/household/month or NPR 16,973/household/annum for a 20 kW MHP (the per household consumer surplus is similar for 50 kW and 100 kW MHP because the cost of kerosene is constant and the LUCE only varies slightly). Details of the consumer surplus calculations are provided in Annex 5.

151. This analysis uses a lumen-based approach to value total household electricity consumption for lighting, which may return an overestimate or an underestimate, depending on the Willingness to Pay for electricity for other applications.[36] Where data on Willingness to Pay for electricity for other end-uses, such as radio and television especially, is available, more precise calculations of consumer surplus can be determined by separately calculating the consumer surplus from television and from radio usage according to the appropriate demand curves for those end-uses.

152. The vast consumer surplus calculated above represents the virtual savings that an MHP household could accumulate on account of the superior technical performance (on a kilo-lumen-hours basis) of MHP electricity compared to kerosene light-

TABLE 20 | Costs of lighting from kerosene and 20 kW MHP

Type of Lighting	Consumption (kLh/month)	Price (NPR*/kLh)	Remarks
Without project (kerosene)	4.44[35]	71.28	Use of kerosene lamps producing 37 lumens for 4 hours a day, which requires 3 litres of kerosene per month, is assumed. Current price of kerosene (unsubsidized) in Nepal is NPR 105.5/litre.
With project (electricity from MHP)	270	1.63	Use of incandescent bulbs with 15 lumen output per watt assumed. Each household consumes about 18 kWh/month. Levelized unit cost of 20 kW MHP electricity: NPR 24.43/kWh.

*NPR 1 = US$0.0104

[35] Rao (2011)

[36] The demand curve derived is an estimate based on just price and consumption points for kerosene and electricity for lighting. A demand curve for shift in lighting preference that is based on a large and systematic sample would probably show a lower consumer surplus for lighting because, beyond a certain point households may prefer to spend money on other uses of electricity rather than on for lighting alone.

ing and the much lower cost of MHP electricity if it were to consume all 18 kWh for electric lighting. In reality, some of the 18 kWh consumption attributed to the household is likely to be used for other applications, so it would not consume the quantity of lumen-hours assumed in the calculation above, and therefore would not enjoy the associated level of consumer surplus from lighting if the Willingness to Pay for other applications is lower than that for basic lighting.

153. More importantly, the assumption that the household could and would spend the amount necessary to consume 18 kWh at the levelized cost of MHP electricity is an economic construct. It is highly likely that some portion of the household budget would be reallocated to other uses instead of being utilized for electricity consumption, i.e. savings accumulated from the availability of a cheaper form of lighting need not be spent on consuming more lighting, especially considering that consuming 18 kWh at the levelized cost of MHP electricity would significantly exceed the household budget that would have been allocated for kerosene lighting.

3.3.4.4. Benefits from reduced expenditure on energy for productive end-use

154. When electricity from MHPs becomes available, productive end-uses (agro-processing, poultry farming and others) are found to switch from diesel-based generation to micro hydropower. Access to electricity from MHPs enables improvement in productivity of existing activities, such as cereal grinding, rice-hulling and oil expelling. While some households may continue to rely on manual agro-processing or on water mills, mechanical/electrical mills can do the same task more efficiently and faster. With the advent of electricity, households gain by having agro-processing units that are nearer to them and also pay a lower price per kg of grain processed.[37] In turn, entrepreneurs running such units gain by saving on the cost of fuel.

155. The net savings on the purchase of fuel for the most common end-use, agro-processing, has been used as a representation of the benefit from micro hydropower to all productive end-uses. The typical commercial load is a 10 hp (7.5 kW) diesel engine that consumes 1.67 liters of diesel/hour. As per the findings of site surveys, the prevalence of one such agro-processing unit for every 100 households has been assumed. Commercial loads are assumed for 2–3 hours/day (2.5 hours taken as the average) for 20 days per month. This yields 600 operating hours per year per 7.5 kW agro-processing unit.

156. Based on these parameters, the annual expenditure to operate this typical agro-processing unit on diesel fuel (at the current price of NPR 105.5 liter) has been calculated and compared to the expenditure on equivalent electric power (7.5 kW x 600 hours = 4500 kWh). The computation of the LUCE generated from a 10 hp (7.5 kW) diesel engine is presented in Annex 6. Calculation of the levelized unit cost of micro hydropower electricity for 20 kW, 50 kW and 100 kW MHPs is also provided in Annex 5. Table 21 shows details of savings to an agro-processing unit on account of shifting from diesel to electricity from micro hydropower.

TABLE 21 | Net savings for one 7.5 kW agro-processing unit when shifting from diesel to MHP electricity

Type of Energy	MHP Capacity		
	20 kW	50 kW	100 kW
Expenditure on Diesel (NPR*/year)	171,391	171,391	171,391
Expenditure on MHP (NPR/year)	109,426	103,347	97,268
Net savings (NPR/year)	61,965	68,044	74,124

*NPR 1 = US$0.0104

Notes: Annual consumption of 4,500 kWh equivalent. Levelized unit cost for diesel generation: NPR 38.09/kWh. Levelized unit cost of MHP electricity for 20 kW, 50 kW and 100 kW MHP, respectively: NPR 24.32/kWh, NPR 22.97/kWh, NPR 21.62/kWh.

[37] Typically, MHP based agro-processing units charge NPR 1–2 less/kg of grain processed.

TABLE 22 | CER revenue potential for MHPs of different capacities (at 23.8 percent PLF)

Installed capacity	CERs	CER revenue (NPR*/year)
20 kW	41.8	28,063
50 kW	104.4	70,157
100 kW	208.8	140,314

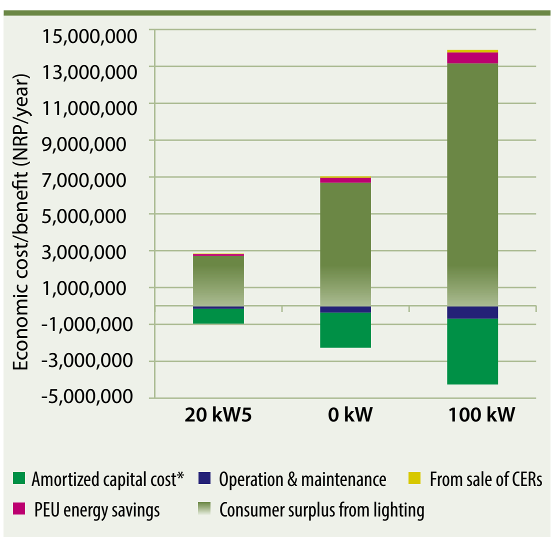
*NPR 1 = US$0.0104; 1 CER = 1 ton of CO_2 eq

157. This differential represents the net saving per annum on energy expenses for a 7.5 kW agro-processing unit, which has then been extrapolated to average commercial loads of 20 kW, 50 kW and 100 kW MHPs to arrive at the annual economic benefit for productive end-use for MHPs of these sizes.

3.3.4.5. Benefits from sale of CERs

158. As per the CDM-PDD on MHPs in Nepal, submitted by the AEPC and registered with the United Nations Framework Convention on Climate Change (UNFCCC), diesel has been accepted as the baseline (or business as usual) option for providing electricity in rural Nepal. The CO_2 emissions coefficient for diesel is 0.9 kg/kWh. Thus, for every unit of electricity generated from an MHP, an equivalent amount of diesel is avoided and emissions of CO_2 mitigated. Table 22 presents the CER revenue potential for 20 kW, 50 kW and 100 kW capacity MHPs.

Figure 16: Summary of annual economic costs and benefits of standalone MHPs



159. Emission reduction from MHP amounts to 2.09 tons of CO_2/year/kW of installed capacity. As can be seen above, at a negotiated price of NPR 672/CER,[38] the value of CERs for a 100 kW MHP operating at approximately 24 percent PLF is NPR 140,314/year (see Annex 5).

3.3.4.6. Summary of economic benefits and costs from MHP

160. Analysts have identified a number of important benefits that they attribute to accessing electricity. This includes higher household income, increased production and productivity (from efficiency gains through electro-mechanization), time saved (and therefore time available for productive activity or recreation), better education indicators, health benefits from improved indoor air quality and better awareness (particularly with respect to nutrition and fertility), as well as women's empowerment. Methodological limitations restrict the scope of this analysis to three categories of benefits that can be more reliably quantified: (i) the consumer surplus from the provision of electric lighting to households, (ii) the savings on fuel from switching from diesel to micro hydropower for agro-processing, and (iii) the CER revenues from avoided CO_2 emissions.[39]

161. Benefits on account of income increase in households[40] and from new productive end-uses have not been taken into account since the cause–effect relationship between the provision of electricity and the benefits is not very clear. For example, it is not clear what has caused the increase in household incomes for MHP-connected households compared to non-electrified households. Similarly, the net profit from an end-use such as poultry farming cannot be attributed entirely to the provision of electricity. Even when benefits from electricity provision are estimated for an end-use, such as agro-

[38] Price/CER is US$7 (US$1 = NPR 96). This is the rate that has been offered by the World Bank for micro-hydro based emission reduction in Nepal.

[39] Since the estimation of economic benefits from lighting apply to the entire domestic load, the benefits from utilization of TV, radio and other household appliances are imputed in this value, albeit imprecisely. Similarly, the calculation of fuel savings for agro-processing is applied to the entire commercial load of an MHP and thus includes an approximation of fuel savings from other productive end-uses as well.

[40] UNDP (2011) has estimated an increase in yearly income of US$121/household for MHP connected households over non-electrified households.

processing in this study, only the benefits from reduced expenditure on diesel have been estimated. Such estimates exclude the likely benefits of a shift from manual or water mill based agro-processing to MHP. The economic benefits estimated are therefore conservative. Figure 16 displays a summary of the economic benefits and costs from 20 kW, 50 kW and 100 kW MHPs operating at 24 percent PLF.

162. As can be seen above, the economic benefits from micro hydropower arise overwhelmingly in consumer surplus from electric lighting. Given that the load for most MHPs is heavily weighted towards domestic consumption for lighting, and given the relatively low level of consumption for productive end-use, this is not surprising. However, when using a lumen-based approach to calculate consumer surplus, as has been done here, the consumer surplus may be overestimated if the penetration of more efficient lighting options, such as compact fluorescent lamps (CFLs), prompts households to reduce their monthly electricity consumption, rather than maintain or expand consumption through the utilization of additional bulbs or other household appliances. This is particularly likely to be the case with MHPs that have installed metering systems. This consumer surplus calculation is also based on the assumption that households are consuming almost the entire load that is available to them (up to 125 W/household), and therefore the MHP is operating at close to capacity at peak hours. Based on these parameters from Figure 16, Table 23 provides a summary of results of the economic analysis of 100 kW, 50 kW and 20 kW MHPs running at 24 percent PLF.

163. As can be seen in Table 23, rural electrification through MHPs returns substantial economic benefits. All three sizes of MHPs considered generate healthy economic rates of return, and the net present value ranges from NPR 17.73 million for a 20 kW MHP to more than NPR 91 million for a 100 kW MHP.

164. The results are fairly similar for all three sizes of plants because most of the costs and benefits have been taken as scalable in a linear manner. However, in reality, some of the repair and maintenance costs would be step costs. For example, the cost of replacing an ELC would be nearly the same for a 20 kW system and a 100 kW system. Due to lack of specific data on repair and maintenance costs, this has been estimated at 2 percent of capital costs. Similarly, smaller plants cannot provide sufficient starting currents for inductive loads and therefore, cannot support the standard agro-processing motors of 7.5 kW. But for a 20 kW MHP this should not be a problem, if all agro-processing units do not start up simultaneously. Apart from this, all other costs and benefits are nearly linear and thus, the above analysis should present a fairly accurate picture.

TABLE 23 | Summary of results of the economic analysis

Parameter	20 kW	50 kW	100 kW
NPV (NPR* million)	17.75	45.00	91.16
EIRR	33.71%	35.52%	37.51%
LUCE (NPR/kWh)	24.32	22.97	21.62
LUBE (NPR/kWh)	68.08	67.34	66.57
Benefit/Cost ratio	2.80	2.93	3.08

*NPR 1 = US$0.0104; LUCE = Levelized unit cost of electricity; LUBE = Levelized unit benefit of electricity

TABLE 24 | Parameters for diesel generation equivalent to 20 kW MHP

Input Parameters	Units	Value
Plant size	kW	20
Plant life	Years	15
Capital cost of diesel generation set (less 13% VAT)	NPR million	0.62
Transmission and distribution system (T&D)	NPR million	2.73
Total capital cost	NPR million	3.35
Specific fuel consumption of diesel	l/kWh	0.33
Economic cost of diesel	NPR/l	105.50
Hours of operation in a year	hr	2,400
Operations and maintenance (O&M) for every 250 hours of operations	NPR	10,000
Annual O&M cost for 2400 hr of operation	NPR	96,000
Overhaul for every 6000 hr of operations	NPR million	0.15
Escalation	%	5%

Note: T&D cost is taken to be the same as for a 20 kW MHP.

TABLE 25 | Parameters for SPV equivalent to 20kW MHP

Input Parameters	Unit	Value
Plant life	Years	20
PV Panel capacity	kWp	42
PV Panel cost	NPR* million	4.07
Power electronics (inverter, charge controller) capacity	kW	30
Power electronics cost (less 15% customs duty, 13% VAT and 13% tax on inverters)	NPR million	2.06
Battery capacity	Ah	7000
Battery cost (less 15% customs duty and 13% VAT)	NPR million	3.89
Transmission and distribution (T&D) system	NPR million	2.73
Labor/transport cost	NPR million	1.63
Total capital cost	NPR million	14.38
Annual O&M		2%
Annual O&M cost	NPR million	0.29
Escalation	%	5%
Cost of battery replacement (every 6th year)	NPR million	3.89
Cost of power electronics maintenance (every 6th year)	NPR million	0.41

*NPR 1 = US$0.0104; T&D cost is taken to be the same as for a 20 kW MHP.

165. Clearly, the economic benefits of an MHP, irrespective of the size, are far greater than the economic costs. Thus, there is a strong reason to support the delivery of electricity through MHPs. However, it could also be argued that the benefits of rural electrification could probably be delivered through other energy technologies or by extending the grid; and the cost of delivery could be different offering a different value proposition. The next section explores this issue.

3.3.5. COMPARISON TO OTHER TYPES OF GENERATION

166. The preceding section showed that there are considerable benefits to be realized from rural electrification, primarily from the provision of electric lighting for households. It is worth considering whether these benefits can be delivered at a lower cost through other means, such as diesel and solar photovoltaic (SPV), which represent the most feasible alternatives in Nepal. Therefore, the cost of delivering the same quantum of electricity and level of service provided by a 20 kW MHP through a SPV system and through a 20 kW diesel plant were examined.

167. Table 24 indicates the parameters used to calculate LUCE from a 20 kW diesel plant.[41] As a comparable diesel plant would be expected to provide the same level of service as an MHP (i.e., about 22 kWh per household per month), this diesel plant is assumed to operate for 5 hours in the evenings for domestic electricity consumption and for 2.5 hours during the day to serve the commercial load in the community.

168. Similarly, the same level of service delivered by a 20 kW MHP could be provided through a SPV system, but the system would need to be optimized to be able to meet the evening lighting load (through sufficient storage capacity) and should feature an inverter that can deliver the reactive power required for 10 hp motors for productive end-use during the day time. The parameters of a SPV solution that could provide the level of service equivalent to a 20 kW MHP is given in Table 25.[42] Given the difficulties faced with repairs and replacement in rural areas, costing for better quality components was done (e.g. batteries and inverters that come with 5-year

[41] Diesel generation cost data based on interview on August 21, 2014 with Mr. Rajesh Kumar Singh, Manager, MAW Engineering (P.) Ltd., Kathmandu, which represent Escorts, Greaves Cotton and Perkins range of engines.

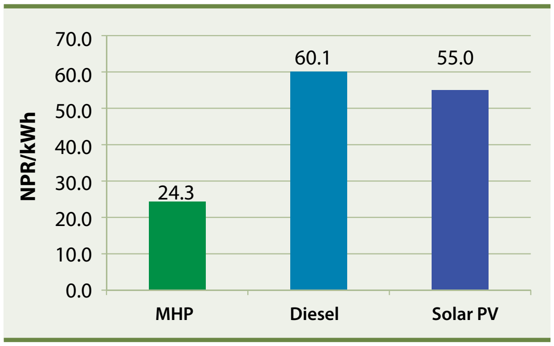
[42] Solar PV parameters and cost data based on consultation on August 22, 2014 with Anjal Niraula, Business Micro-grid Lead, Gham Power Pvt. Ltd.

warranty), which veered towards the upper end of the cost range.

169. Based on the parameters stipulated in Table 24 and Table 25, the LUCE from the different forms of energy is presented below in Figure 17. Analysis was based on a 20 kW MHP, a 20 kW diesel plant and a 42 kWp SPV system at 6 percent discounted rate. The calculations are based on economic costs and the assumption that transmission and distribution costs account for approximately 35 percent of the total cost of the MHP. Accordingly, 35 percent of the cost of a 20 kW MHP is included as transmission and distribution cost in the calculation of levelized costs for diesel and solar PV scenarios. The calculation of levelized unit cost for diesel-based generation and distribution and SPV-based generation and distribution are provided in Annexes 6 and 7, respectively.

170. It can be seen from the figure that the LUCE from a 20 kW MHP is considerably less than that from a diesel plant or solar PV system delivering the same level and quality of service. Whereas the levelized unit cost for diesel and solar PV are fairly similar, the levelized unit cost for MHP electricity is less than half of that for the other energy alternatives considered and thus represents the best value for money for rural electrification. Since the level and quality of service have been fixed when costing the competing alternatives, the economic benefits derived from each of the options is identical, but the economic costs of MHP are more attractive by a large margin. Therefore, where technically feasible, MHP represents the least cost option for providing off-grid communities with access to electricity.

Figure 17: Comparison of LUCE for various generation sources



3.3.6. INSTITUTIONAL PERFORMANCE

171. A variety of organizational forms are practiced in the management of MHPs. They could be legal and registered business entities, such as cooperatives and companies or even individual entrepreneurs and recognized groups (usually MHFGs) drawn from the user community. Community managed MHPs were successfully pioneered during the REDP and following the changed subsidy policy of 2006, MHFGs have emerged as the largest organizational form to manage MHPs. Although ESAP, the other large micro hydropower program that was managed by the AEPC, did not favor a particular form of organization, today the AEPC actively promotes only community managed MHPs. Table 26 shows the organizational forms managing the MHPs visited during the site survey.

172. Except for the Midim Kholan MHP (which is under construction) and the Yafre MHP (which is temporarily under repairs), the rest of the MHPs were found to be operational. This in itself is a testimony to the management capabilities of the local community.[43] Moreover, some of the MHPs are more than 10 years old and are still functioning well.

173. In all the MHPs visited, customers were satisfied with the quality of service and the response of the management in addressing problems. Despite expressing the need for more energy to serve their ever-increasing needs, most of the customers closely identified themselves with the MHP and its performance.

174. On the tariff front, managers have displayed a great degree of innovation and understanding of the community's needs. Tariffs have been set in consultation with the community and care has been taken to ensure that they are affordable, while also covering at least the operational costs. In Siwai Khola, a newly commissioned MHP, customers were being charged NPR 300 for the first 10 kWh and NPR 10/kWh for every additional kWh. The high initial tariff is to pay off the debt component of the capex as soon as possible and make the MHP debt free.

[43] In the Village Energy Security Programme that India ran during 2007–2010, local community found it very difficult to handle the technology (biomass gasification) and Village Energy Committees that were set up to manage the energy systems were largely ineffective.

TABLE 26 | Organizational forms of MHP management

Name of MHP	Location	District	Organizational Form
Gottikhel MHP	Gottikhel	Lalitpur	Private limited company
Midim Kholan MHP	Ishaneshwor	Lamjung	Cooperative
Bhujung MHP	Bhujung	Lamjung	Sub-committee of Conservation Area Management Committee under the guidance of ACAP
Ghandruk I MHP	Ghandruk	Kaski	Sub-committee of Conservation Area Management Committee under the guidance of ACAP
Ghandruk II/Bhirgyu MHP	Ghandruk	Kaski	Sub-committee of Conservation Area Management Committee under the guidance of ACAP
Daram Khola I MHP	Wamitaxar	Gulmi	Cooperative
Daram Khola II MHP	Wamitaxar	Gulmi	Private entrepreneurs in partnership with a local school
Giringdi Kholan MHP	Kharbang	Baglung	Cooperative
Malekhu I MHP	Mahadevsthan	Dhading	Cooperative
Malekhu II MHP	Mahadevsthan	Dhading	MHFG
Yafre MHP	Yafre	Taplejung	MHFG

175. Overall, as discussed earlier, the MHPs are being run as social enterprises and therefore, tariff is not set to maximize profits, but to adequately cover costs. However, costs of major repairs are not factored in adequately and this often results in the MHFG going back to the users to collect money to pay for repairs.

176. The evident success of the MHFG in the face of similar institutions facing failure in India[44] is mainly on account of the excellent community mobilization and preparation activities undertaken by the AEPC starting from the REDP in 1996. The six principles followed by the AEPC to foster a strong sense of participation, ownership and thereby management among the community are shown in Table 27.

3.3.6.1. Observations on institutional performance of standalone MHPs

177. Overall, it is concluded that MHPs are being managed well. MHFGs and cooperatives (that MHFGs usually evolved into) have shown a high degree of commitment and capacity to manage the complex task of implementing a micro hydropower project. Indeed, the task involves managing several activities and actors spanning from community management to vendor management, to financial closure, and others. Equally important is the successful model of community mobilization and empowerment that the AEPC has promoted. A key factor is also the substantive contribution of the community in setting up the MHP, which ensures that they manage its operations and maintenance well. The AEPC would do well not to significantly reduce the share of the community in the capex.[45]

178. A strong sense of shared ownership and pride in the MHP among the community has helped enormously in collecting electricity charges from users. This usually has been the bane of rural electricity distribution businesses elsewhere. During the mobilization of the community and formation of MHFGs, the importance of making adequate profits and creating a repair and maintenance fund should be emphasized. The site-visit impression has been that the community at large and the MHFG see their role as one of delivering electricity as social goods. The community does not see electricity generation as one that leads to business development in the area and they certainly do not view the MHP itself as an income generation opportunity.

179. If a part of the income from the MHP is channeled back to the community (shareholders in the MHP) in the form of dividends on investments then there

[44] India: Biomass for Sustainable Development: Lessons for Decentralized Energy Delivery Village Energy Security Programme, World Bank, 2011
[45] AEPC may offer concessional financing to lower entry barriers, but dilution of local contribution should be avoided.

TABLE 27 | Six principles followed by the AEPC for management among the community

Community mobilization principle	Activities	Key observed results
Organization Development	• Community organizations[46] are formed well before the process of planning an MHP. • MHFG is formed by each community organization sending its representatives. • MHFG is given the task of coordinating and managing all activities pertaining to design, installation and commissioning of the MHP. • It is also tasked with mobilizing funds from the community, VDC, DDC, etc. • On commissioning of the MHP, they are responsible for day-to-day operations and management of the MHP. • They have to report to the community periodically on the progress, utilization of funds and revenues and expenditure after commissioning of the MHP. • The MHFG has a tenure of 3 years and elections are held periodically.	• Due to systematic mobilization of the community, MHFGs are truly representative of the community and enjoy their confidence. • The fact that they are able to mobilize nearly NPR 20,000/household demonstrates the confidence that they enjoy. • Public presentation of progress and other details ensures transparency • This is testified by the fact that there are very few MHFGs that have misappropriated money collected or mismanaged finances. • Key result is the strong sense of ownership among the community and the equally strong sense of purpose among the MHFG. • This is reflected in the community putting up sums of money or labor to pay for costs of repair and maintenance that could not be covered by operational profits alone. • The fact that many MHFGs have gone on to be registered as cooperatives is a direct result of the excellent organization and development efforts. • Formation of the cooperative puts the MHP on the path to a proper business organization form.
Capital Formation	• Each member of the community organization(s) has to save a certain amount on a weekly basis. • The amount is pooled and used for mutual lending for both productive and consumption purposes.	• Having a fund at their disposal gives a sense of security to the community to meet any challenge. • Handling savings and credit teaches the community the skills of accounting and the importance of transparency in dealings; both lessons that are important for managing large investments such as for MHPs. • The act of savings and lending binds the community together and results in a better sense of team play. • The habit of savings leads to better mobilization of funds for the MHP.
Skill Enhancement	• Training in operations and maintenance is given to operators picked up from the local community of the MHP. • Local operators are also well equipped to handle minor problems. • Training is also given for enhancing skills in bookkeeping, administration, management and community development.	• Technical training to local operators is a key reason behind the successful technical performance of MHPs. • Book keeping skills are reflected in the good account keeping seen in most of the MHPs. • Many of the MHPs visited were issuing receipts for electricity charges collected reflecting systematic operations.
Technology Promotion	• Several productive end-uses are promoted and training is given to interested entrepreneurs.	• In general, where special efforts have been made productive end-uses have emerged. • However, it is to be noted that electricity is often only an enabler and a not a driver. • Access to markets, local resources and access to finance are real drivers for productive end-uses to emerge. • Nevertheless, the approach of productive end-uses has shown promising results.
Environment Management	• Importance of environment in ensuring livelihoods and quality of life. • Contribution of MHPs and RETs in protecting the environment.	• Has created a good sense of importance of the environment and how MHPs contribute to it.
Women's Empowerment	• Special emphasis is given to the participation and role of women in community organizations and MHFGs.	• During the site visit discussions were held with several women members of MHFGs as well as MHP cooperatives. • In a predominantly male dominated hierarchical society, that Nepal is, the role, participation and knowledge of women with respect to MHPs and the functioning of MHFG was impressive.

46 Community organizations are similar to self-help groups, but consists of both men and women.

would be more interest in running the MHPs as a business. Currently, this does not seem feasible due to low PLFs and low tariffs. In fact, the low tariff itself may be viewed as a way of transferring profits to the community, but doing it overtly would draw attention to profit making as an objective of MHP management.

180. If the MHP were to be connected to the grid there would be considerable profits and a sound profit sharing mechanism including standard rules and practices would need to be devised. Therefore, grid-connected MHPs should be viewed as a business that helps the community to earn an income from a local resource without destroying it.

3.3.7. STAKEHOLDERS' PERFORMANCE

181. The performances of various stakeholders that help deliver an MHP are analyzed herein. The roles of the community and the MHFG have already been discussed in the previous sections.

3.3.7.1. Analysis of the Project Cycle for setting up an MHP

182. To better understand the roles and performance of the stakeholders, it is essential to analyze the project cycle for setting up an MHP.[47] The process begins with the demand creation followed by the community making a request to the AEPC through the RSC and/or the DDC for setting up an MHP for them. This step usually precedes a process of community mobilization that has been described in the preceding section. Figure 18 shows the various steps once the application for helping a community set up an MHP is received by the RSC.[48]

Figure 18: Steps, processes and outputs of the MHP project cycle

Step	Process	Output
Demand Creation	Awareness generation through media and village visits by RSC	Community becomes interested in MHP Community mobilization and MHFG formation starts
OBSERVATIONS ▶	This takes 6 months to a year and is essential since the community is the project developer and manager	
Demand Processing	Community makes an application to the RSC/ DEECCS/AEPC; the RSC conducts a pre-feasibility analysis and recommends for DFS preparation	AEPC sanctions DFS. Community with RSC support selects DFS consultant from a list of AEPC pre-qualified consultants.
OBSERVATIONS ▶	This takes about 1-2 months. Community pays 50 percent of its share as an advance to consultant	
DFS Preparation and Approval	DFS is prepared by the consultant and report submitted to RSC. AEPC releases 40 percent of subsidy for DFS preparation. RSC verifies DFS and submits to AEPC which verifies it and either asks for revisions or accepts it	DFS is revised and/or accepted. Conditional approval for subsidy release is made by AEPC to CREF.
OBSERVATIONS ▶	Community releases 50 percent of its share of DFS cost. This process may take up to 6-9 months depending on AEPC workload and quality of DFS. This is a bottleneck currently, mainly on account of quality of the DFS.	

[47] The project cycle for setting up an MHP has been presented in Section 2.3, Figure 8.

[48] The current practice is for the District Environment, Energy & Climate change Office (DEECCS) to only process applications up to 10 kW and for the rest the RSC is the agency on the ground.

Step	Process	Output
Mobilization of Funds	MHFG begins mobilization of balance of funds from the community, VDC, DDC, other donors and banks. RSC provides handholding support	MHFG mobilizes the funds and deposits 80 percent of it in cash in a designated community managed account.
OBSERVATIONS ▶	This is a make or break step. This takes about 1-3 years. Some communities may fall away at this step. However, this step makes the community take strong ownership of the project and readies them for the project implementation stage. Some soft loans would help speed up the process, but equity in hard cash should not be diluted too much given that they run the MHP as a social enterprise.	

Step	Process	Output
Selection of installer	RSC calls for online bidding from pre-qualified installers, forms a Bid Evaluation Committee which includes the MHFG Chairman	Lowest bidder is selected as the installer and MHFG enters into a contract for installation and commissioning of MHP. MHFG releases 50 percent of its share as advance; AEPC gives 60 percent of subsidy as advance against bank guarantee. After a joint site visit by the installer, RSC and DFS consultant, the balance 10 percent is released to them
OBSERVATIONS ▶	This takes about 2-3 months. This process is well laid out and is understood well by all stakeholders. Selection of the lowest bidder has reportedly resulted in several new installers quoting 50 percent lower than the estimated amount in the DFS. AEPC should carry out an analysis of all bids received in a year and especially verify abnormal bids. The process of the joint site visit before installation starts, puts great onus on the DFS consultant to do a sound job and also provides the installer an opportunity to verify the DFS before signing the contract with the MHFG	

Step	Process	Output
Installation of MHP	Civil works by MHFG and electro-mechanical by installer. Installer is responsible for all aspects of MHP installation	MHP installation is complete and ready for testing and commissioning. Bank guarantee is released on delivery of electro-mechanical equipment at site. Community pays its share simultaneously. RSC/DEECCS provides verification
OBSERVATIONS ▶	This takes about 1-2 years depending on the terrain and funds flow. Some installers reportedly do not complete the task on time and misuse the funds given to them. MHFG is at their mercy during this stage.	

Step	Process	Output
Power output test (POT) and Verification	POT is done by RSC in the presence of MHFG, installer and AEPC, and the plant is commissioned. Power output verification (POV) is conducted by a 3rd party inspector usually during November-May (lean flow season)	Successful POT results in a commissioning report and release of 20 percent to installer. After POV, another 10 percent is released. Quantum of final subsidy amount is determined after POT and POV. If generation is less, subsidy is reduced and excess payment recovered from installer. At the end of 1 year another check is conducted. If satisfactory, balance 10 percent subsidy is released to installer
OBSERVATIONS ▶	POT takes 2-3 months. POV is done usually within the year of commissioning. Largely, the QA only verifies the power output and is at the end of commissioning. There is no material and in-process verification of electromechanical components that attract 50-60 percent of total costs. In effect, the quality of the work under the direct control of the installer is verified only after commissioning. Oversight of civil works is not stringent as installer deputes a technical person only for providing marking and level. RSC cannot physically serve many installation sites with their manpower. Thus, QA is a weak link in the MHP installation and commissioning process; especially the quality of electromechanical equipment.	

TABLE 28 | Status of pipeline of MHP projects during the NRREP period

Particulars	Under Construction	Conditionally Approved	Detailed Feasibility Study	Demand Collection	Total
Identified demand numbers of MHP	167	263	219	185	834
Total (kW)	5,418	8,071	5,839	6,401	27,397

183. Observations on key stakeholders' performance are presented herein.

3.3.7.2. Alternate Energy Promotion Centre

184. The AEPC is the main institution that designs, drives and manages the micro hydropower program in Nepal. It is driven by its mandate to provide energy access to rural Nepalese through renewable energy sources in a cost effective manner. Micro hydropower is one of the key RETs that it promotes for achieving this objective.

185. After the lull in the early 2000s due to political conflict in Nepal, the AEPC has successfully brought the micro hydropower programs back on track. However, as discussed earlier (see Figure 9), at the current growth rate it will be difficult to actually implement a 25 MW aggregate capacity on the ground by 2017. Table 28[49] shows the status of the pipeline of micro hydropower projects during the first NRREP period.

186. As mentioned in the previous section on the project cycle, the AEPC should take steps to improve the quality of DFS being prepared, and make the quality monitoring process (especially during installation) more stringent and concurrent. And, it should definitely institute the following steps.

- Given that electromechanical components are nearly 50 percent of the total cost of an MHP and a major part of the installer's off-site cost, AEPC should carry out a 3-stage inspection process covering the materials stage, in-process stage and pre-shipment inspection.
- A 3-stage inspection will ensure that the quality of the components delivered at the site is as per design and material specifications;[50] and will provide a solid standard for pre-qualification of installers and manufacturers rather than just depending on documented evidence of capability, as is being done now.
- On the lines of the biogas program, the AEPC should put in place a comprehensive post-installation survey of MHPs and monitor a sample of projects. A sampling plan may be drawn such that MHPs installed in a particular year are monitored for a maximum period of five years after commissioning. The sample drawn could be relatively higher during the first year and gradually tapered off to zero by the fifth year. Thus, a new set of samples would be added every year from new MHPs installed while the few that have been monitored for five years would be dropped out of the sampling plan.
- The above two measures would provide a proper basis to pre-qualify DFS consultants and installers, and also monitor the performance of the RSCs.

187. A consistent feedback by the installers on the project cycle is that it takes too long for decisions to emerge from the AEPC. This is understandable since the AEPC is highly centralized in its decision making process. Of late, it has completely decentralized the decision-making process for pico hydropower to the DEECCS, but it is yet to do so for micro hydropower. However, reportedly there are moves afoot to set up regional centers of AEPC with powers to sanction MHPs as well. This is a step in the right direction, however, given the vast sums of money involved and the large number of projects being executed, the AEPC should progress cautiously. The present system of approvals is well thought out with adequate checks and balances, but AEPC's decision-making is not the only bottleneck.[51]

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49 Based on "Micro Hydro Power Development in Nepal", Madhusudhan Adhikari, National Adviser, Community Electrification, AEPC/NRREP

50 Use of mild steel in place of stainless steel for making jet nozzles, using copper coated aluminium plates for earthing were some of the quality issues mentioned during our discussions with RSC and manufacturers

51 Indeed, a major cause for delay after the installer has been chosen is the time taken by the community to mobilize its share, which may take from 6 months to 2 years.

188. Overall it is concluded that the AEPC is performing well in promoting and setting up MHPs in Nepal. In installing 25 MW of MHP, the AEPC would have successfully mobilized NPR 5,000 million by way of community contribution from rural Nepal.[52] However, a key challenge in scaling up MHPs would be community fund mobilization and quality of equipment, installation and service. Furthermore, apart from the subsidy and other financial support (which has been planned well), the AEPC also needs to increase technical human resources along with more engagement from the private sector to achieve the 25 MW target by 2017 along with the quality control activities listed above.

3.3.7.3. Regional Service Centres

189. RSCs are usually NGOs that are entrusted with the responsibility of promoting RETs among rural communities. In all there are nine RSCs for promoting MHPs in Nepal. Each RSC covers 5–10 districts and has about 8–10 personnel for promoting MHPs. Of these 2–3 engineering staff that provide technical support, while 3–4 field coordinators provide on ground support for community mobilization and organization development.

190. RSCs have a crucial role to play in the project cycle for an MHP. From demand creation to installation and commissioning of the MHP, they are involved in every stage. They play the role of mentoring the community in general and the MHFG in particular in setting up an MHP. They are local verifiers of progress and provide supervisory support to the AEPC during the project cycle.

191. Each RSC has a target for total installed capacity of MHPs that it has to help set up every year. In addition, it also has a target for enabling the setting up of productive end-uses in MHPs, both old and new. Thus, the skills-set needed for the range of tasks that the RSC has to perform is large and varied. Overall, the RSCs are found to be competent and capable of performing their roles. The steady stream of micro hydropower projects in the pipeline is testimony to this fact. However, it is to be noted that they are too stretched to provide adequate oversight on quality aspects of equipment, civil construction and installation. Furthermore, oversight provided by RSCs is mainly visual and does not involve any equipment to make actual measurements.

192. The role of the RSC would be crucial and their capabilities would come under huge stress during scaling up of the micro hydropower program. In addition, with the new initiatives of mini-grid and grid connectivity coming up, their capabilities should be built up, especially in technical matters, by periodic trainings, exposure visits and workshops to exchange knowledge and practices. As key partners of the AEPC and their extension in the field it would be useful for the AEPC and the RSCs to interact frequently.

3.3.7.4. District Environment, Energy and Climate Change Section

193. Under the REDP, DEECCS's role was equal to that of the RSCs. But since the REDP ended, the AEPC has preferred to work with and through the RSC for implementation of the micro hydropower program. Currently, DEECCSs are restricted to pico hydropower projects and other RETs. However, they are also responsible for providing oversight to MHPs during installation and expected to assist the DDC in technical matters related to RETs.

194. Until recently, when the DEECCSs were handling MHPs as well, they had assistant staff in the form of social and community mobilizers in addition to an officer, usually an engineer. The officers now have no assistance and are themselves in the process of being absorbed by the DDC. There is good cooperation between the staff of the RSC and the DEECCS, which is useful while seeking clearances for water rights or for mobilizing funds for MHPs. The AEPC should take care to ensure that DEECCSs even after their absorption in to the DDC receive periodic training and are part of the sharing and planning events that it may organize from time to

[52] Interestingly, DoED, the parent ministry for NEA has proposed a Peoples' Hydro Power as a programme to kickstart new power generation initiatives. It aims to mobilize local governments and local institutions as investors in the hydropower sector. It is proposing to provide a subsidy of nearly 75 percent to the DDC for setting up small hydropower projects.

time. DEECCSs are RET specialists that the AEPC has helped place in the DDC and should continue to nurture them.

3.3.7.5. DFS Consultants, Installers and Manufacturers

195. Currently, there are 61 pre-qualified DFS consultants and 78 pre-qualified installers for various capacities of MHPs. Thus, on an average each DFS consultant is preparing 3–4 DFSs every year while each installer is installing 2–3 MHPs. Taking an average size of 30 kW, this is approximately NPR 15,000,000 to 18,000,000 of turnover/installer/year. At a net profit margin of 10 percent this is approximately NPR 1,500,000 to 1,800,000 turnover/installer/year.

196. For manufacturers with large manufacturing investments who are also installers, this is not very attractive and hence the feedback from larger manufacturers is that the industry has got very crowded. On the other hand, for installers who outsource every component and play the role of system integrators, this is attractive.

197. This could be one reason why newer installers are able to offer competitive bids while larger manufacturers are not able to match them. Indeed, it appears that some of the installers are importing components when it is cheaper to do so rather than procure from local manufacturers. Overall, while this will help bring down costs, there is a need for caution with respect to quality. The abnormally low quotes from a few installers should be investigated.[53] Quality of manufactured components, the cost of equipment, capacity, and interest in MHP manufacturing would be crucial to any MHP scale-up program in Nepal.

198. Given the ever-increasing installation cost of MHPs, the AEPC should in collaboration with the NMHDA institute a thorough engineering review of the manufacturing process and establish benchmark costs for the various MHP components. Interactions with manufacturers and installers during the field survey revealed a lack of systematic costing of manufactured components. Quotations are based on thumb-rules rather than on any engineering-based costing. Furthermore, most manufacturers custom-make components for each site rather than use standardized components to fit a site. While this delivers the best efficiency in energy generation, it makes the equipment costly.[54] Therefore, the AEPC should help the micro hydropower industry standardize its components. A review of the manufacturing, benchmarking of costs, and standardization, will together help reduce costs.

199. Use of "pumps as turbine" is a time-tested approach in India and other countries especially for medium heads. Typically, pumps cost only 30–40 percent of the cost of a custom-made turbine and could help reduce costs significantly.

200. Given the low volumes of business, large manufacturers are losing interest in the micro hydropower sector. The AEPC should take steps along with the NMHDA to build the capacity of the industry to manufacture and install mini hydropower plants. Apart from providing training and exposure to manufacturers, the AEPC should also start supporting more mini hydropower plants. Further, it should also identify appropriate technology to harness the hydropower potential of low heads and large flows that are prevalent in the lower hills and the Terai belt of Nepal. Currently, in India, with technology received from Japan an "ultra low head MHP"[55] is being utilized on a quasi-commercial basis with support from the United Nations Industrial Development Organization (UNIDO). This would help open up a whole new area of business to the micro hydropower industry.

201. Currently, manufacturers and installers are clustered around the Kathmandu valley and Butwal. If the micro hydropower industry specialists and installers are largely system integrators, then there is no need for them to be based in Kathmandu or Butwal. Being closer to the area where future growth is expected would bring down costs of delivery signif-

53 One reason could be the need for having completed at least one MHP installation for a conditionally qualified installer to be treated as fully qualified. Therefore, new installers try to secure an order even by offering services below cost.

54 Given the low utilization of the plant it is a moot point if efficiency should be maximized or optimized with cost.

55 Works with 1–3 m heads.

icantly. The AEPC should encourage entrepreneurs in other parts of the Nepal hills to take up this task.

202. As a first step, they should encourage at least 2–3 entrepreneurs as "local repair centers" to take up repair and maintenance for every 100 MHPs under the guidance of the installer/manufacturer. For example, areas such as Taplejung, Panchthar, Terathum, and Illam have only one manufacturer in Biratnagar as an option for service. If an installer from Kathmandu sets up an MHP, it takes more than a day's journey to reach the site for after-sales service. In such situations, a mal-functioning plant remains closed down for a long period and the community is rendered helpless.

203. With a large base of functional MHPs, the AEPC should give after-sales service priority by decentralizing repair and maintenance, and especially enabling onsite repairs.

204. Finally, quality inspection of manufactured components should be done in three stages: (a) material inspection, (b) in-process inspection, and (c) pre-shipment inspection. This is crucial to maintain the high operational rate of MHPs in the field especially with a large number of new installers coming on board in the past few years. A comprehensive approach to consistently track and rate the performance of the installers and the MHPs installed by them should form the basis for pre-qualification.

3.4. MHP MINI-GRID

205. Interconnection of standalone MHPs into a local grid is termed a mini-grid. Often, as a community's power needs grow, isolated MHPs are unable to meet the growing demand. In such cases, a mini-grid could become the next available option. To form a mini-grid, some standalone MHPs must have power in surplus and others a power deficit. By connecting these MHPs to form a mini-grid, the power can be balanced between communities served by isolated MHPs, especially during off-peak and peak hours. Furthermore, with mini-grids, in case one or two MHPs are shut down, the others can continue to supply power although in limited loads (or to a small distribution area) thereby increasing system reliability compared with isolated MHPs.

206. However in Nepal, mini-grids have been planned as one of the strategies to connect to the grid when it arrives in the vicinity of an MHP. The AEPC has been trying to form mini-grids that are at least 100 kW or more in size[56] in response to NEA's reluctance to let an MHP of less than 100 kW size to connect to the grid.

207. In Nepal, mini-grids have only been attempted as pilot projects. One such mini-grid is already operational since 2012 at Rangkhani, near Kushmishera in Baglung district. Therefore, technical reliability, financial viability and economic benefits of mini-grids are not fully confirmed. Furthermore, in the context of the NEA removing the 100 kW threshold for grid connection, the relevance of the mini-grid has significantly decreased. Therefore, they could be implemented in some situations if financially feasible.

3.4.1. TECHNICAL RELIABILITY

208. The successfully implemented pilot mini-grid project in Baglung indicates that a mini-grid is technically reliable. The main challenges related to interconnecting MHPs are synchronization and load sharing between them. To achieve synchronization, the three-phase synchronous generators (alternators) of the interconnected MHPs must have the same voltage and frequency. Additionally, they must be connected to each other at the moment the three phases of one alternator line-up with the three phases of the other alternator.

209. Generated voltage of an alternator is controlled by regulating the excitation DC voltage, which produces the magnetic field in the alternator. This is achieved by an automatic voltage regulator (AVR), which constantly measures the fluctuations in the generated voltage and regulates the excitation voltage accordingly. Frequency of a generator fluctuates

56 Given the latest decision of NEA's board to allow any size of MHP to connect to the grid, this reasoning for forming a mini-grid may not be tenable any more.

with fluctuations in load. Therefore, the load of the MHP must be kept constant to generate electricity at a constant frequency. To achieve this, MHPs use ELCs that divert the difference between the generated power and consumed power to dummy loads (ballasts). A synchronoscope measures the phase voltages of the alternators and makes the interconnection at the time the phases are lined up.

210. Even though ELCs can be found in international markets, these are very costly in terms of low-cost MHP installation. In Nepal, locally made low-cost alternatives are available but these tend to be less reliable and prone to breakdowns and malfunctions. Moreover, inadequate protection systems make these more susceptible to damage by fault currents.

3.4.2. ABILITY TO MEET POWER NEEDS

211. Mini-grids become pertinent where some of the nearby standalone MHPs have a power surplus while the others have a power deficit. The MHPs with power deficit can be upgraded to deliver more power; however, upgrading entails large quantities of civil and electrical works. At the same time, the MHPs with power surplus are wasting power when nearby MHPs with power deficit have an immediate need for more electrical power. By connecting these individual MHPs, loads can be shared between them to balance the surplus in some MHPs with the deficit in some others.

212. The problem of load sharing is handled by conducting a load flow study. This study simulates the power delivered to probable loads and the losses in interconnection links (transmission lines) of a mini-grid. If one of the MHP's is shut down, the load flow study also indicates the loads that have to be disconnected from the mini-grid for proper operation.

3.4.3. FINANCIAL VIABILITY

213. Usually, MHPs in standalone mode suffer not only from low PLFs but also peak deficit during evening hours (17:00–22:00 hours) when most households are drawing power from it. During the rest of the period, they have very low loads and many hours when there is no load at all and the power generated is either dumped into the ballast or the MHP is simply shut down.

214. When a few MHPs with surplus power during peak times, a few MHPs with peak deficit, a few MHPs with high loads during non-peak hours and a few MHPs with no loads/low loads during non-peak hours are interconnected and operated as a single distribution system, the overall PLF of the interconnected system is expected to be higher than the weighted average PLF of the individual MHPs taken together.

215. The reason for the higher system PLF is for better utilization of surplus capacities and is the primary basis for forming a mini-grid of MHPs. It is pertinent to note that if there is no surplus during peak time in a few of the MHPs in the mini-grid, then there would be no improvement in quality and quantity of electricity delivered to households. Similarly, if there are no significant productive end-uses coming up during non-peak hours, then the PLF of the mini-grid does not improve significantly. More importantly, since productive end-use tariffs are usually higher than household tariffs, not having sufficient productive end-use loads will lead to little increase in revenue for the mini-grid.

216. Major costs incurred in forming a mini-grid of MHPs are in drawing of 11 kV high tension lines to evacuate power from each MHP and inject it into the distribution grid, installing appropriate ELCs with synchronoscopes which will automatically sense the mini-grid parameters (voltage, current, phase and frequency), and in matching the MHPs own parameters to synchronize the generating MHP with the mini-grid. In addition, microprocessor-based controllers sense the size of the load from the load centers and dispatch power from different MHPs in proportion to their installed capacity.

217. Finally, appropriate and adequate protection systems are needed to ensure there is no backflow of current when an MHP is shut down for repairs and maintenance. Usually, the largest MHP is treated as the master and it sets the mini-grid parameters for other MHPs to match. In addition, it is used to provide the necessary reactive power and active power to charge the HT lines and transformers.

TABLE 29 | Details of feasibility studies of mini-grids

Parameter	Baglung/ Rangkhani	Giringdi Khola cluster	Gaudi Khola Urja Valley	Tikhedhunga	Ghandruk	Chomrong
No. of MHPs in mini-grid	6	8	6	2	4	3
Mini-grid capacity (kW)	107	267	104	80	161	67
Households	1,200	1,994	870	225	607	91
Incremental capex (NPR*)	15,029,500	44,367,311	22,535,295	5,756,878	15,347,815	8,018,264
Incremental capex/kW (NPR)	140,463	166,170	216,686	71,961	95,328	119,676
Incremental PLF	17 percent	13 percent	25 percent	12 percent	9 percent	8 percent
Basis for calculating PLF	Based on presentation referred to below	Expected to be achieved after 5 years after forming mini-grid		Taken at 75 percent of surplus capacity available during off-peak hours for productive end-use only		
Study carried out by	Presentation by Bhupendra Shakya, RERL, AEPC[57]	Shine Technocrats Pvt. Ltd., Kathmandu for AEPC[58]		Oshin Power Services Pvt. Ltd., Butwal for ACAP[59]		

*NPR 1 = US$0.0104

218. Thus, the capital cost incurred in setting up a mini-grid depends on the number of MHPs being interconnected, the length of the high tension line and the extent of load development expected which would determine the need for distribution transformers. However, the first two factors greatly determine the capex of a mini-grid.

219. Given that the formation of a mini-grid is expected to result in a higher PLF for the mini-grid as a whole, due to reasons mentioned above, incremental analysis has been used to assess the financial performance of mini-grids. Table 29 shows details for a few mini-grids drawn from several detailed feasibility studies commissioned by the AEPC and ACAP.

220. The capex is generally higher for a mini-grid with a larger number of plants that are being interconnected. This is self-evident, because irrespective of plant size the cost of interconnection is the same for a 10 kW MHP and for a 100 kW MHP. Furthermore, the distance between the MHPs also determines the capex. Table 29 shows that on an average the cost/kW of mini-grid capacity incurred as capex is NPR 135,000; while, the cost/kW for a new MHP ranges from NPR 400,000 to NPR 450,000 (see sub-section on financial analysis of MHP as standalone).

221. The incremental PLF resulting from the mini-grid is largely dependent on how much surplus capacity is available in the mini-grid and more importantly how much of it is actually used. In general, most MHPs have a peak load deficit (17:00–22:00 hours) and surplus during off-peak hours. Table 30 shows the estimated surplus in the mini-grid feasibility study carried out in the ACAP MHP clusters. Incremental PLF is estimated by all these studies by making first order estimates of productive end-use loads that could come up during off-peak hours. For example, the above-mentioned study in the ACAP MHP clusters has assumed that 75 percent of all surplus capacity would be used for a period of eight hours (09:00-17:00 hours) by productive end-uses.

222. The study carried out by Shine Technocrats assumed a gradual increase in productive end-use loads culminating in a peak load of 189 kW and 105 kW for the Giringdi Khola and Gaudi Khola mini-grids, respectively. However, in the present study for simplicity of analysis, it has been assumed that incremental PLF is reached in the first year of the mini-grid operation itself. Table 31 presents the financial performance of mini-grids based on details presented in the preceding paragraphs.

57 A Community Managed Micro Hydro Connected Mini Grid in Nepal — Challenges and Opportunities, Bhupendra Shakya, February, 2013 at Berlin.
58 DPR for Interconnection Of MHPS in Baglung District, Shine Technocrats Pvt. Ltd, October, 2013.
59 Report on Feasibility Study of Local Micro-Grid Connection in ACAP Cluster Areas, Oshin Power Services Pvt. Ltd., November, 2013.

TABLE 30 | Estimated surplus in the mini-grid's feasibility study carried out in ACAP MHP clusters

Cluster	MHPs	Plant Capacity (kW)	Surplus power (kW) Peak time (17:00-22:00)	Surplus power (kW) Off-peak time (09:00-17:00)
1	Sabed	40	0	25
	Ulleri MHP	40	1	18
2	Siwai Kholan MHP	26	7	21
	Chane Kholan MHP	35	5	25
	Bhirgyu Kholan MHP	50	1	15
	Ghandruk-I Ph. MHP	50	0	15
3	Ghatte Khola-I MHP	30	0	12
	Ghatte Khola-II	12	0	5
	Ghatte Khola-III	25	0	9
Total		**308**	**14**	**145**

Source: Report on Feasibility Study of Local Micro-Grid Connection in ACAP Cluster Areas, Oshin Power Services Pvt. Ltd., November, 2013.

3.4.3.1. Observations on financial analysis of mini-grids

223. From the above analysis it is clear that while some mini-grids make operating profits (income is able to cover operations and maintenance, and salaries, but not depreciation and servicing of loans), all of them fail to make net profits. Furthermore, an analysis of the Baglung mini-grid shows that smaller plants are generating more power than before, but are making losses overall due to increased operations and maintenance, and salaries.

224. Given that the investment needed for every kilowatt of a mini-grid is between 30–50 percent of the capex of a new MHP, the returns do not seem to be commensurate with the investments. It is not clear how the productive end-use loads would increase in such a substantial way once the mini-grid is formed, when evidence from existing standalone MHPs of 100 kW shows otherwise.

225. It can be argued that a mini-grid of 100 kW capacity is not very different from a 100 kW MHP as standalone in load development. Therefore, substantial efforts would be needed to step up load development in mini-grids to reach the PLFs projected above. Thus far the experience of developing productive end-use loads, especially during off-peak hours has shown that while electricity is an enabler, it does not drive the development of such loads. The underlying business drivers such as demand, access to markets, and roads are more important in developing such productive end-uses.

226. Finally, from a technical, financial and managerial perspective, it is easier to operate and manage a single plant of 100 kW serving 1,000–1,200 households spread over a large area than to deliver the same service through a mini-grid of several smaller MHPs. Mini-grids should be viewed as a "retrofitting" approach to help smaller MHPs serve their load centers better by cooperating with other MHPs that may have surplus capacity.

227. From a policy point of view, mini-grids should be taken up only after a thorough case-by-case examination of their technical and financial feasibility is done based on realistic projections of load development. Indeed, it is better to promote larger plants and draw transmission and distribution lines to link up several communities rather than base the planning on the needs of a few wards in a VDC. The experience from Baglung and few more mini-grids that the AEPC is supporting will provide more (realistic) data, which will then shed light on whether mini-grids are worth pursuing.

3.4.4. ECONOMIC ANALYSIS

228. Where generation assets already exist, such as in the case of existing MHPs, the capital costs and the operation and maintenance costs associated with the construction and operation of the constitu-

TABLE 31 | Financial performance of mini-grids

Name of cluster	Baglung/ Rangkhani	Giringdi Khola cluster	Gaudi Khola Urja Valley	Tikhedhunga	Ghandruk	Chomrong
No. of MHPs in mini-grid	6	8	6	2	4	3
Mini-grid capacity (kW)	107	267	104	80	161	67
Incremental PLF	17 percent	13 percent	25 percent	12 percent	9 percent	8 percent
Incremental kWh	159,344	298,446	224,025	84,096	126,932	46,954
Incremental Tariff (NPR*/kWh)	5	5	5	5	5	5
Incremental income (NPR/year)	796,722	1,492,231	1,120,124	420,480	634,662	234,768
Incremental O&M (NPR/year)	300,590	887,346	450,706	115,138	306,956	160,365
Incremental salaries NPR/year	408,000	504,000	408,000	216,000	312,000	264,000
Incremental expenses NPR/year	708,590	1,391,346	858,706	331,138	618,956	424,365
Incremental operating profits NPR/year	88,132	100,885	261,418	89,342	15,706	-189,597
Depreciation @7 percent NPR/year	1,001,967	2,957,821	1,502,353	383,792	1,023,188	534,551
Interest on loan @ 14 percent on 20@ of capex. NPR/year	420,826	1,242,285	630,988	161,193	429,739	224,511
Profit before taxes. NPR/year	-1,334,661	-4,099,221	-1,871,923	-455,642	-1,437,221	-948,660

*NPR 1 = US$0.0104

Notes:

- *Incremental tariff is the difference between the price at which power is purchased by the mini-grid operator (NPR 4.5/kWh), from the MHPs (operating as IPPs in the mini-grid) and the selling price to the consumer (NPR 9.5/kWh).*
- *Incremental O&M is taken at 2 percent of capex.*
- *Incremental salaries are salaries incurred by the mini-grid operator, which includes 3 support staff and 1 manager. For simplicity sake, it is assumed that there is no increase in salary costs to individual MHPs.*
- *Interest on loan is taken at 14 percent. Debt equity ratio is 20:80.*

ent MHPs that form a mini-grid can be considered a sunk cost and excluded from consideration in the economic analysis of the mini-grid. The analysis will, therefore, only account for the incremental cost associated with the interconnection infrastructure necessary to operate the mini-grid, including the distribution lines and electronic equipment. The additional cost of salaries constitutes a transfer from one set of beneficiaries to another and can therefore be disregarded in the economic analysis. Metering systems promote the optimization of electricity consumption and may be introduced as part of a mini-grid where power-based tariffs used to be the norm (as was the case in the Rangkhani, Baglung mini-grid), but they are not an intrinsic feature of a mini-grid and would provide the same benefits as to a standalone MHP. Thus, the cost of metering systems is also excluded from the economic analysis.

229. The primary benefit of a mini-grid is that it permits more efficient allocation of available electricity, leading to a higher PLF. The economic value of this additional consumption is tied to productive end-use. Since MHPs typically have a peak load deficit (17:00–22:00 hours) and surplus during off-peak hours, it has been assumed that the incremental consumption during peak hours is minimal and that incremental PLF can be attributed entirely to increased consumption during off-peak hours for productive end-use.

3.4.4.1. Estimation of economic costs

230. The economic cost of setting up and operating a mini-grid is derived from financial costs net of all taxes, subsidies and duties. Further, labor costs are deflated to real costs as explained in the section on economic analysis of MHPs as standalone. The economic costs of mini-grids are as shown in Table 32.

3.4.4.2. Estimation of economic benefits

231. The economic benefits of an MHP mini-grid has been calculated as the sum of the "savings-associated reduced expenditure on energy that can be attributed to the mini-grid" and the "CER revenue derived from the avoided emissions".

TABLE 32 | Estimation of economic costs of mini-grids

Parameter	Unit	Baglung (Rangkhani)	Giringdi Khola cluster	Gaudi Khola Urja Valley	Tikhedhunga	Ghandruk	Chomrong
Incremental Economic Capex	NPR*	13,646,254	40,283,948	20,461,250	5,227,041	13,935,273	7,280,300
Incremental Capex per kW	NPR	127,535	150,876	196,743	65,338	86,554	108,661
Incremental O&M - Economic	NPR/ year	266,009	785,262	398,855	101,892	271,643	141,916

*NPR 1 = US$0.0104

Notes: For Giringdi Khola and Gauda Khola mini-grids, the applicable VAT indicated in the feasibility study is deducted to calculate incremental economic capex. For Ranghanki, Tikhedhunga, Ghandruk and Chomrong mini-grids, 13 percent VAT is deducted from 80 percent of capex (assumed to be the share of electromechanical equipment) to arrive at the economic cost. Economic cost of O&M is taken as 2 percent of capex, less VAT.

3.4.4.3. Benefits from reduced expenditure on energy for productive end-use

232. The productive end-uses that are made possible by the availability of mini-grid electricity would have otherwise had to rely on isolated diesel motors. The levelized unit cost of generation from a typical 10 hp (7.5 kW) diesel engine therefore constitutes the expense that is avoided by utilizing electricity from micro hydropower instead. Accordingly, the economic benefit from the increased PLF is calculated as net savings on energy for productive end-use from a shift from diesel to electricity, where the electricity cost is taken to be the unique levelized total unit cost of generation and distribution for each mini-grid. Table 33 presents the net savings on energy per year for each mini-grid.

3.4.4.4. Benefits from sale of CERs

233. Increased electricity consumption for productive end-use displaces the consumption of diesel in such enterprises. These avoided emissions result in CERs that could fetch additional revenue to the mini-grid. Table 34 displays the annual revenue that could accrue to a mini-grid from the sale of CERs.

3.4.4.5. Summary of economic benefits and costs

234. Figure 19 displays a summary of the economic benefits and costs for each of the six mini-grids analyzed. Economic benefits exceed economic costs, often by a considerable margin, for each of the mini-grids, except for Chomrong, which is the smallest mini-grid consisting of three MHPs with a combined capacity of 67 kW.

235. As seen in the financial analysis of mini-grids, costs vary with the number of MHPs being interconnected and the distance between the MHPs, while interconnection costs are the same irrespective of the size of the MHPs being interconnected. Benefits are directly proportional to increase in PLF. Thus costs and benefits are unique to each mini-grid and therefore, any decision to embark on a mini-grid project should be informed by careful consideration of site-specific costs.

236. As shown in Table 35, the net present value is positive and the benefit–cost ratio is above one for all the mini-grids except the Chomrong mini-grid, where the incremental benefits of the mini-grids do not justify the incremental costs. As indicated in Table 33 above, the Chomrong mini-grid features a low combined capacity of 67 kW and is only projected to achieve a modest increase of 8 percent in PLF. On the other hand, the Giringdi Khola cluster mini-grid boasts the highest installed capacity of the mini-grids examined, but it also comes with onerous costs attached, diminishing its economic viability to some extent.

237. Given that increase in PLF (especially through sale of off-peak power) is key to the economic performance of a mini-grid, it is clear that significant investment other than merely in mini-grid infrastruc-

TABLE 33 | Net savings on energy per year for each mini-grid

Parameter	Unit	Baglung (Rangkhani)	Giringdi Khola cluster	Gaudi Khola Urja Valley	Tikhedhunga	Ghandruk	Chomrong
Mini-grid capacity	kW	107	267	104	80	161	67
Incremental PLF	%	17%	13%	25%	12%	9%	8%
Incremental electricity consumption	MWh	159.3	298.4	224.0	84.1	126.9	46.9
Diesel LUCE	NPR/kWh	38.09	38.09	38.09	38.09	38.09	38.09
Avoided diesel expenditure	NPR millions	6.07	11.37	8.53	3.20	4.83	1.79
Mini-grid LUCE	NPR/kWh	17.3	20.3	16.7	17.2	19.7	21.3
Expenditure on electricity	NPR millions	2.76	6.04	3.74	1.44	2.50	1.00
Net savings	NPR millions	3.31	5.33	4.79	1.76	2.34	0.79

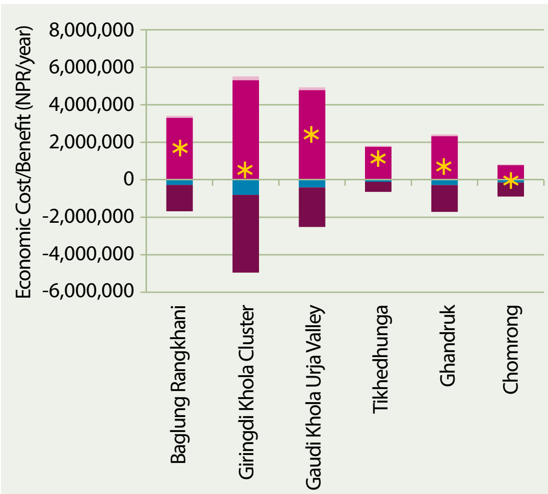
Note: Diesel consumption of 0.22 liters to generate the equivalent of 1 kWh equivalent in mechanical energy is assumed.

ture will be necessary to achieve the incremental PLF.[60] Thus, a few more pilot projects in mini-grid are required to conclude whether it is worthwhile to continue in this direction (see Box 3).

238. An important limitation of this analysis is that it only counts as benefits the net savings on energy for productive end-use and the revenue from the sale of CERs. Various analysts have pointed to the broad benefits (in terms of increased household income, health and educational outcomes, women's empowerment, etc.) that can come about as a result of electrification as described in the economic analysis of standalone MHPs, and it might be expected that some such broad benefits may also arise from the additional consumption of electricity, but due to methodological limitations and concerns such benefits are not included in this analysis.

239. The main reason that the economic analysis of a standalone MHP is favorable is due to the vast consumer surplus associated with the delivery of electrical lighting to households. This benefit is absent in the analysis of mini-grids due to the assumption that increases in peak load for domestic lighting would be rare, if at all, due to most MHPs already operating at or close to peak load capacity. Data from published literature suggest that this is a reasonable assumption, and has also been validated by field surveys conducted as part of this study. Accordingly, the economic benefits arising from an additional unit of electricity consumed due to mini-grid development is notably lower than those arising from a unit for domestic consumption.

Figure 19: Summary of the economic benefits and costs for six mini-grids



*For a 15-year plant life at a 6 percent discount rate.

60 Substantial investment of time and resources in building local capacity and the necessary ecosystem for additional productive activity has been made in Rangkhani by the Government and by other development partners.

TABLE 34 | Projected annual benefits of mini-grid from sale of CERs at US$7/$tCO_2$

Parameter	Unit	Baglung (Rangkhani)	Giringdi khola cluster	Gaudi Khola Urja Valley	Tikhedhunga	Ghandruk	Chomrong
Avoided emissions	tCO_2eq/year	159.3	298.4	224.0	84.1	126.9	47.0
CER revenue	NPR*/year	107,079	200,556	150,545	56,513	85,299	31,553

*NPR 1 = US$0.0104

Notes: Default emission factor of 0.9 kg CO_2eq/kWh utilized. Average technical distribution losses = 10 percent. CER price at US$7/$tCO_2eq$, which amounts to NPR 672 at the current exchange rate of US$1 = NPR 96.

TABLE 35 | Summary of economic benefits of mini-grids

Parameter	Baglung (Rangkhani)	Giringdi khola cluster	Gaudi Khola Urja Valley	Tikhedhunga	Ghandruk	Chomrong
NPV (NPR* millions)	15.92	2.62	22.05	11.03	5.89	-1.26
EIRR (%)	21.35	7.01	20.30	31.92	12.12	3.11
LUCE (NPR/kWh)	17.32	20.27	16.73	17.15	19.68	21.33
LUBE (NPR/kWh)	21.44	18.49	22.03	21.61	19.08	17.43
Benefit/Cost Ratio	1.92	1.05	1.85	2.67	1.33	0.86

*NPR 1 = US$0.0104; LUBE = levelized unit benefit of electricity. LUCE = levelized unit cost of electricity.

3.4.5. INSTITUTIONAL PERFORMANCE

240. Although, currently there is only one mini-grid in operation in Nepal there is considerable agreement within the AEPC and other stakeholders on the institutional set-up needed to manage the mini-grid. Briefly, individual MHPs are operated and managed as IPPs, while the distribution network is managed by the mini-grid operatorcooperative formed with the membership of all electricity users in the distribution area. This arrangement provides clarity in the operations and is therefore preferred.

241. However, it often leads to lack of clarity on the roles of the MHFGs and the cooperative as institutions. One question that can arise is whether the individual MHPs are expected to maximize their profits or should the cooperative's interest override. Once an MHP begins working as an IPP, it tends to seek a higher price for sale of power to the cooperative to maximize its profit. Customers on the other hand put pressure on the cooperative to keep tariffs low. MHFGs which hitherto were accountable to the customers in their distribution area (before the mini-grid was formed) both for operating the MHP as well delivering power at affordable tariffs now view maximizing profits as their main objective. Thus, the differing objectives of the MHPs as IPPs and the cooperative being responsible for delivering affordable power to the community can often lead to conflicts.[61] This is further exacerbated when smaller MHPs make lower profits or even losses due to higher operating costs with growth in revenue not being commensurate with increased costs.

242. Currently in the Baglung mini-grid system, FITs are set at the same level for all MHPs in a mini-grid. This however, does not take into account that operational cost/kWh for MHPs differ from one another. Usually, larger plants have a lower operational cost/kWh since salary costs are a step cost (increasing with every shift worked) and do not vary significantly across the sizes of MHPs. Therefore, when tariffs are set for purchasing power from MHPs, care

[61] At the time of this study, the Baglung mini-grid is the only operational mini-grid. However, it is reasonable to expect this behavior in future mini-grids as the roles of generation and distribution are separated and each entity acts to make itself viable.

should be taken to ensure that every MHP's operational costs are being fully met with the revenue generated by them.

243. Overall, it can be concluded that in the Baglung pilot an institutional model where MHPs serve as IPPs with the mini-grid operator acting as a local load dispatch center and also doubling as a distribution network manager is currently being tested. A few more pilot projects will help draw better lessons before changes are integrated in the institutional model.

3.5. MHP GRID CONNECTION

3.5.1. TECHNICAL RELIABILITY

244. As discussed earlier, the technical performance of standalone MHPs is relatively good. When such MHPs are to be grid connected, they need to meet NEA's grid connection criteria. The MHPs must maintain voltage and frequency levels (among others) as well as meet all of the grid safety requirements. For example, the supply voltage of the MHP at major connection points should not deviate by more than +10 percent of the nominal value. Similarly, the fundamental frequency of the power supplied by the MHP must be maintained between 48.75 and 51.25 Hz (+2.5 percent of 50 Hz). Additionally, the maximum transmission loss should not exceed 4.5 percent of the received energy (see Annex 3). Such standards and requirements for grid connection enforced by the NEA require high technical reliability and certain modifications (see Box 4) of grid-connected MHPs.

245. When the national grid arrives in the distribution area of the MHP, it can be interfaced with the national grid in various configurations[62] as follows: (1) Option 1: Connect the MHP generator to the national grid and allow the national grid to take over the local distribution services. (2) Option 2: Connect the MHP generator and the local distribution grid to the national grid with provisions for providing power to the local community through the MHP generator and the local distribution grid during load shedding or outages on the national grid. (3) Option 3: Shut down the MHP generator and local grid and have the customers switch over to the national grid (for details on Options 1, 2 and 3, refer to Section

Box 3: A PROMISING MINI-GRID IN PHUNGLING, TAPLEJUNG

Phungling Bazaar is centrally powered by a 125 kW Sobuwa Kholan MHP which only generates 80 kW for 24 hours and a 250 kVA diesel generator set which generates 160 kW during the daily eight-hour peak period. The diesel generator set consumes 320 liters of diesel to operate for eight hours. With the escalation in diesel prices in the international market, operating expenses of the diesel generator set are very high resulting in increase in electricity tariffs to recover these operating costs. The tariff charged to the consumers is set at NPR 175 for the first 10 kWh, NPR 22/kWh for 10 kWh–25 kWh and NPR 25/kWh for 25 kWh and above. Rest of the demand is supplied by distributed diesel generator sets (in isolated mode, i.e. not synchronized with the 250 KVA large generator) owned by various small-scale industries, offices, banks and other enterprises.

The AEPC and RERL have considered an integrated approach to fulfill the electricity demand of Phungling Bazaar. Under this plan, they have considered implementing the following three measures side by side: upgrading the existing Sobuwa Kholan MHP to generate at full capacity of 125 kW, constructing a new mini hydropower plant called Middle Phawa Khola to generate 400 kW, and interconnecting eight nearby MHPs into a mini-grid capable of supplying 660 kW of off-peak power and 492 kW of peak power. The total estimated budget for this integrated power system is NPR 190,368,258.00 (US$1,983,002.68). According to the AEPC, the proposed mini-grid will cost NPR 57 million with an NPV of NPR 55 million and an IRR of 27 percent (see Annex 8).

62 "A Guidebook on Grid Interconnection and Islanded Operation of Mini-Grid Power Systems Up to 200 kW", Chris Greacen, Richard Engel, Thomas Quetchenbach. Lawrence Berkeley National Laboratory & Schatz Energy Research Center April 2013

Box 4: MODIFICATIONS REQUIRED FOR GRID CONNECTION OF MHP

An isolated MHP with its own local distribution grid must be modified in the following ways to operate in grid connected mode in addition to providing power to the local community during load shedding:

- Disable the frequency control by the ELC and enable power factor control by AVR while grid connected. Conversely, enable frequency control by ELC and enable voltage control by AVR while serving the community during load shedding on the national grid (i.e. during islanding mode).
- Connect safely to the national grid by ensuring appropriate frequency and phase sequence.
- Provide quality power to the national grid with appropriate power factor, as well as voltage and low harmonic distortion.
- Disconnect safely and quickly from the national grid during disturbances and load shedding and reconnect after such events.

A single line diagram of an MHP with required modifications for grid connection with provisions for islanding is given in Annex 9.

3.5.5. Institutional Performance). (4) Option 4: Buy bulk power from the national grid to provide additional power to the local community through the MHP's local distribution grid. Meanwhile, the local MHPs can continue to operate in their distribution areas and not supply to the grid. (5) Option 5: Use the MHP generator and distribution grid only as a backup during load shedding or outages on the national grid. In this option, the MHP generator will not be connected to the national grid but will supply the local distribution grid in isolated mode during load shedding hours on the national grid.

246. In terms of the benefit provided to the community as well as the MHFG, it is advisable to pursue Option 2.[63] If this option is pursued, there are four specific benefits. First, the MHP's PLF will improve and the MHFG can generate additional revenue from selling electricity to the grid. Second, the invested resources of the community and the GoN in building the MHP are prevented from being wasted. Third, the local community gets unlimited power from the national grid and limited power from the MHP during load shedding on the national grid. Fourth, the national grid adds a consumer base (previously the MHP's consumer base) with marginal investment. However, this option is the most challenging to pursue and includes the problem of islanding as discussed in Annex 9.

3.5.2. ABILITY TO MEET POWER NEEDS

247. The ability of grid-connected MHPs to meet the power needs depend on the modality of such a grid connection. If the MHPs are connected to the grid only and not to the distribution area, then the ability to meet the power needs of the distribution area will depend on the power available in the NEA's nearest sub-station, the length and voltage level of the incoming transmission line as well as the technical parameters of the line.

248. On the other hand, if the MHPs are connected to the grid but are also designed to supply power to the local distribution area, then they will be able to function (within their distribution area and up to their capacity limit) when the NEA resorts to load shedding. The advantage here will be that the distribution area will have electricity supply during load shedding hours and the MHP's PLF will also improve. Another option in such a system is for the MHP to supply electricity to the distribution area and sell surplus power/energy to the grid.

3.5.3. FINANCIAL VIABILITY

249. With the NEA grid being extended into many parts of the mid-hills of Nepal, there is strong apprehension among the community (local investors) and the AEPC about the future of the MHPs installed

[63] Curiously, discussions with NEA revealed that they are interested in Option 1, where MHP becomes an IPP and sells power exclusively to the grid, while NEA takes over the distribution network and treats the community as its normal customer.

in the area. There is a concern that these investments could get stranded if efforts are not made to connect them to the grid. However, until recently the NEA was not very keen on permitting such isolated MHPs to connect to the grid citing technical issues, and especially the concern that it would compromise grid quality and result in several safety problems.

250. Overall, the NEA has agreed to permit MHPs of 100 kW capacity[64] and above to connect to the grid. Among the sites visited under this study, the Midim Khola (100 kW) MHP was built specifically for connecting to the grid and supplying power to it as an IPP. Financial analysis of a grid-connected 100 kW MHP is presented in this section assuming that it would supply power that is surplus after meeting the needs of the local community. Accordingly, as described in the preceding sections on MHP as a standalone, a PLF of 23.84 percent is taken as the local requirement. Of the rest, it is assumed that 90 percent would be sold to the NEA giving a PLF of 66 percent[65] from selling power to the grid. Taking into account the power sold to the NEA and power supplied to the local community, the overall PLF rises to 90 percent from 23.84 percent when the MHP was operated as a standalone system. Table 36 shows details of the values for key parameters used to carry out the financial analysis.

3.5.3.1. Results of financial analysis of grid-connected MHPs

251. The analysis is presented here at two levels:

- To ascertain if the incremental investment in grid connectivity yields attractive returns through an incremental analysis, and
- To ascertain if the increased revenues from connecting to the grid make the MHP financially viable, taking into account both MHP capex and the cost of making the grid connection. This analysis

TABLE 36 | Details of parameters used for financial analysis of grid connection

S. No.	Parameter	Estimated value used in financial analysis
1	Plant size in kW	100 kW, 50 kW and 20 kW
2	Life of the plant in years	15 years
3	Capital cost of the plant	NPR* 40,000,000 for 100 kW, NPR 21,250,000 for 50 kW, NPR 9,000,000 for 20 kW plus NPR 4,900,000 for connecting to the grid. In addition, NPR 1,000,000 for every km of 11 kV line drawn from the MHP to connect to the grid. Distances assumed are 0, 1, 2, 5, 10, 20 km.
4	Financing mix, including debt	50 percent subsidy, 40 percent equity, 10 percent loans
5	Component-wise capital cost	58 percent electro-mechanical, 18 percent civil structures, 24 percent others.
6	Loads: domestic and commercial	Domestic: 18 kWh/household/month Commercial: 4–5 kWh/household/month
7	Plant load factor	23.84 percent (local supply), 66 percent (grid). Overall, 90 percent PLF
8	Tariff	NPR* 6/kWh-domestic, NPR 8/kWh-commercial, and NPR 6.0/kWh sold to grid[66]
9	Operations and maintenance cost	3 percent of total capex annually. This is higher than for standalone operations since the plant will be run 24x7 once it is grid connected and wear and tear is expected to be higher
10	Salary and administrative cost	NPR 18,000 for three operators, NPR 8,000 for an accountant and NPR 10,000 for MHP manager. Total NPR 36,000/month
11	Depreciation	7 percent on straight line basis on 76 percent of capex
12	Tenor and terms of loan	14 percent rate of interest, 7 years term

*NPR 1 = US$0.0104

64 NEA has now agreed to permit any size of MHP to connect to the grid. Therefore, the analysis covers 20 kW, 50 kW and 100 kW over various distances of an 11 kV line drawn from the MHP and connected to the grid.

65 Distribution losses of 10 percent are taken into account before calculating surplus. Hence the total is only 90 percent PLF.

66 As per the recent board decision of the NEA, current rates applicable to IPPs would be offered to MHPs, viz., NPR 8.40 (dry season-4 months) and NPR 4.80 (wet season-8 months)/kWh.

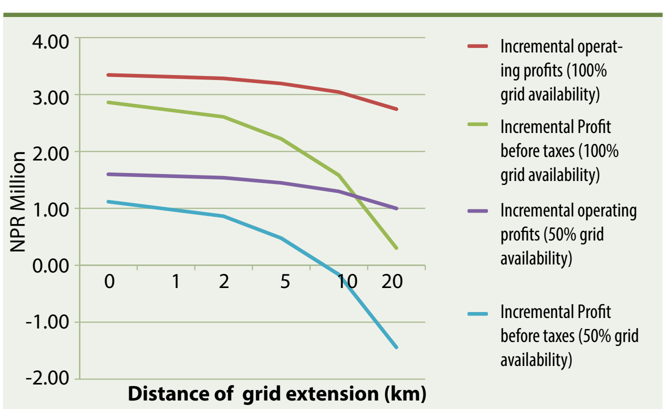
is important because the incremental analysis may provide positive results but if the MHP as a whole does not make profits, or worse, makes greater losses then, the incremental investment is not worthwhile.

252. Figure 20 shows the results of the incremental financial analysis of various sizes of MHPs connected to the grid over various distances and at 100 percent and 50 percent availability of the grid for evacuation of power from the MHP to the grid.

253. Clearly, the incremental investment in connecting a 100 kW MHP to the grid is fully justified by the substantial returns that it gets from sale of surplus electricity to the grid. Even without subsidy, the investment is profitable. However, while incremental operations profits and incremental profits before taxes are positive at both 100 percent and 50 percent grid availability at all distances, incremental profits before taxes are negative for 50 percent grid availability beyond 5 km of grid extension. This indicates the importance of having an assurance of grid availability to evacuate power from the MHP. [67]

254. Similar analyses are presented for a 50 kW and a 20 kW plant connected to the grid over various distances from the grid at 100 percent and 50 percent grid availability in Figure 21 and Figure 22.

Figure 20: Incremental financial analysis of connecting 100 kW MHP to the grid



255. The above charts show that a 50 kW MHP connected to the grid is barely profitable operationally at 100 percent grid availability; it makes profits before taxes only up to a grid distance of 5 km when grid availability is 100 percent. If grid availability is only 50 percent, the MHP makes no profits before taxes, beyond a grid distance of 2 km.

256. On the other hand a 20 kW MHP connected to the grid is clearly financially unviable since the incremental revenue does not cover the incremental expenses at all distances from the grid. This means that such plants may need capital subsidy to be able to connect to the grid, while a 100 kW plant may not need a capital subsidy.

3.5.3.2. Financial analysis of grid connected MHPs on full cost basis

257. However, a more important analysis is whether this investment and the increased revenue from it would make investment in the MHP as a whole profitable. The analysis of standalone MHPs (in the preceding section) showed that they are not profitable and barely cover operational costs even with capital subsidy. Financial analysis for 100 kW, 50 kW and 20 kW MHPs connected to the grid at various distances from it has been carried out.[68] The results covering, financial internal rate of return (FIRR), NPV, LUCE and break-even point (BEP) are presented in the subsequent figures.

258. Figure 23 shows that FIRR is positive only with subsidy, but is well below the interest rate of 14 percent and expected RoE of 16 percent, and thus is likely to be unattractive to bankers and private investors. However, compared to the standalone MHP, the FIRR for a grid-connected 100 kW MHP is substantially higher.[69] The FIRR for 50 kW and 20 kW MHPs could not be calculated due to negative cash flows across all distances.

259. Figure 24 shows that the NPV for a 100 kW MHP that is grid connected is positive only with subsidy and up to a 5 km distance from the grid. In all the other cases including 50 kW and 20 kW (see Figure

67 In India, there is a constant demand from mini/micro hydropower plants connected to the grid to provide them deemed generation status when the grid is not available for evacuating power.

68 Analysis has been carried out with and without capital subsidy. The financing mix is 50 percent subsidy, 40 percent equity and 10 percent loan.

25 and Figure 26) MHPs, it is negative. Results of the break-even analysis are presented in subsequent figures.

260. Figure 27 shows that the number of kWh of sales required to break-even is well below the current sales for a subsidized 100 kW MHP that is grid connected with 100 percent grid availability, up to a distance of 10 km from the grid. Without subsidy, the BEP is well above the current sales indicating that the MHP will not break-even without subsidy. The scope for increasing sales in kWh is limited since the plant is already operating at 90 percent PLF in this scenario. However, if the tariffs were increased, the BEP would shift lower. Figure 28 shows that except for a 100 kW MHP that is connected to the grid at less than 20 km distance all other sizes of plants do not break-even despite a capital subsidy.

3.5.3.3. Observations on financial analysis of MHP grid connection

261. Grid-connected MHPs even at 90 percent PLF are not financially attractive at current tariffs under both subsidized and non-subsidized capex. At current tariffs, without subsidy on capex, the MHP cannot service its loan (10 percent of capex is debt). However, at the LUCE of NPR 8.90 the IRR for the subsidized MHP shoots up to 22 percent and presents a financially attractive proposition. The LUCE that includes a 16 percent RoE, is a true reflection of a subsidized MHP's cost of delivering electricity in a rural setting. The unsubsidized LUCE is a reflection of the full cost basis of delivering 1 kWh of electricity in a rural setting. The current rates being offered by the NEA are a gross underestimate in contrast to the cost that would be incurred by the NEA if it were delivering power by extending the grid to a typical MHP village and has been estimated in the following section.

3.5.3.4. Estimating the cost of delivering electricity in rural Nepal through the national grid

262. An attempt has been made in this section to estimate the cost of extending the national grid to deliver electricity in the rural hills of Nepal. Typically, when the grid is extended it includes an 11 kV line (transmission line) from the nearest substation

Figure 21: Incremental financial analysis of connecting 50 kW MHP to the grid

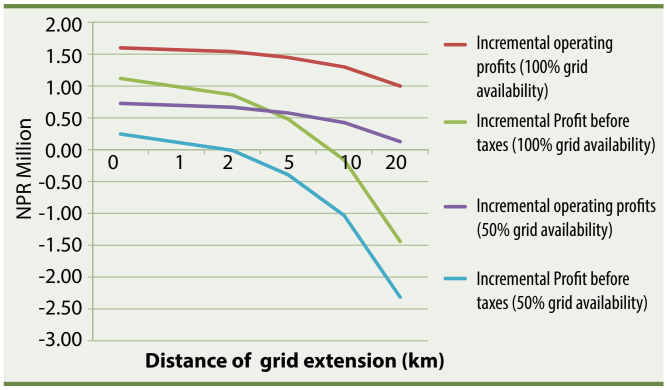
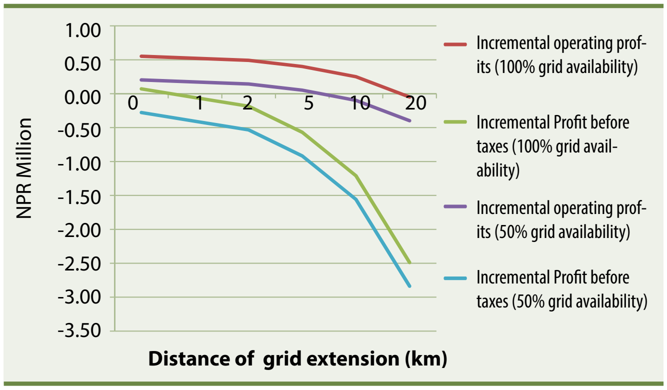


Figure 22: Incremental financial analysis of connecting 20 kW MHP to the grid



to the load center and various lengths of the 400 V line (distribution line) depending on the density of households in an area. Furthermore, depending on the load (kW), the capacity and number of transformers would vary. Table 37 presents the inputs used to derive the estimated cost of grid extension.

263. Based on the above inputs, the LUCE for delivering power in the hills of rural Nepal with a grid extension of 0 km, 1 km, 2 km, 5 km, 10 km, and 20 km and for household density of 50/km2 and 75/km2 and for supplying to 200, 500, and 1,000 households was estimated (see Annex 4). Figure 29 shows the results of the estimation for a density of 50 households/km2 and 75 households/km2 for serving 1,000 households, which is equivalent to the service provided by a 100 kW MHP.

[69] FIRR for a standalone 100 kW MHP could not be calculated due to negative cash flows throughout the lifetime of the project.

Figure 23: IFIRR for grid-connected 100 kW MHP

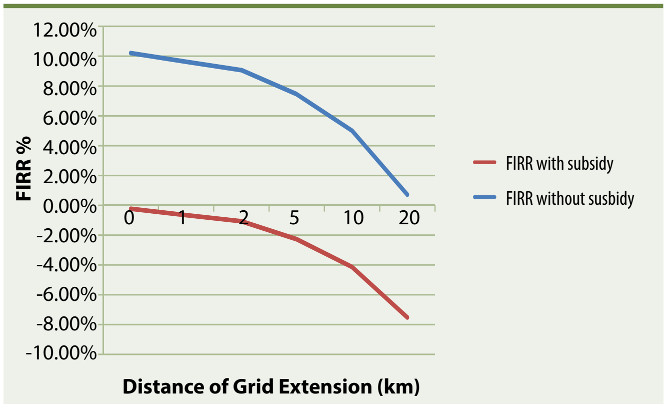


Figure 24: NPV for grid connected 100 kW MHP

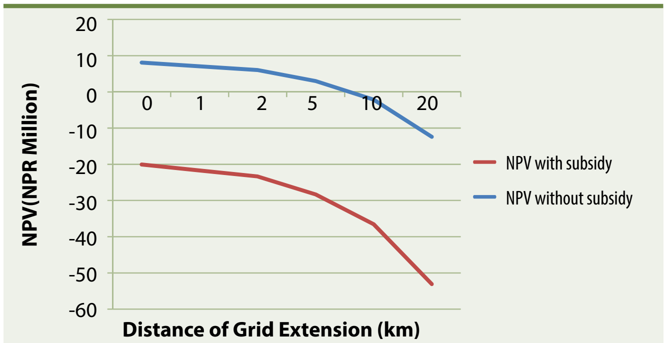


Figure 25: NPV for grid connected 50 kW MHP

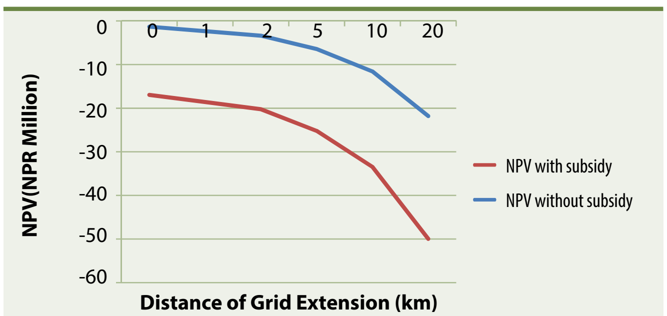
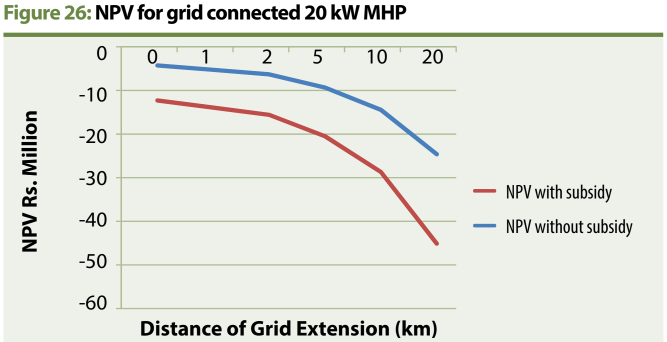


Figure 26: NPV for grid connected 20 kW MHP



264. The levelized cost of delivering 1 kWh of electricity by extending the grid to serve 1,000 households with a density of 75 households/km2 ranged from NPR 17 to NPR 25 depending on the length of the grid extension. In comparison, Figure 30 shows that the levelized cost of 1 kWh of electricity from a grid-connected 100 kW MHP without subsidy ranged from NPR 11 to NPR 13.

265. Figure 31 compares the LUCE of subsidized grid-connected MHPs, and the current NEA tariff for IPPs and NEA's cost of delivery. Clearly, the NEA's cost of delivery is higher than the LUCE for even a 20 kW grid-connected MHP. Further, the current IPP tariff being offered to the MHPs for connecting to the grid is well below the NEA's own cost of delivering power to a remote community. Thus, it is cost-effective for the NEA to let MHPs supply power to local communities rather than extend the grid and force the MHP to shut down. For every kWh supplied by the MHP to the local community, the NEA would save NPR 6.0 (NPR 17 less NPR 11).

266. If the NEA purchases power from the MHP to supply to areas around the MHP by extending the grid, it saves on operational costs even if it purchases at NPR 11/kWh which is the full cost LUCE for a grid-connected MHP operating at 90 percent PLF.

267. On the other hand, if the NEA buys electricity from an MHP at the subsidized LUCE of NPR 9.00 it makes substantial savings over its cost of delivery, which is NPR 17/kWh in the rural Nepal hills. Therefore, there is considerable scope for NEA to offer higher PPA rates to grid-connected MHPs than is being offered now. These comparisons have been made for 0 km grid extension. As the distance increases, the difference in LUCE for an MHP and the NEA cost of distribution (CoD) increases.

268. The MHP also benefits by increasing its profitability if the PPA price is revised to reflect the true cost of delivery (including 16 percent RoE) for grid-connected MHPs. Thus, while the LUCE of NPR 9.0 represents a realistic cost plus return on equity structure for a 100 kW MHP after accounting for

subsidy, the levelized CoD for NEA represents the avoided cost.

269. Overall, it can be concluded that a grid-connected MHP that is able to evacuate surplus power to the grid round the clock is profitable, provided the PPA is signed at a rate that covers capital and operating costs, and offers reasonable RoE. At current tariffs, it is not profitable.

270. Thus, if the PPA is signed at a reasonable rate to cover costs and guarantee return for every kWh supplied to the grid, many private sector companies and cooperatives would be interested in making investments as is the case for larger hydropower plants.

271. Finally, from the NEA's perspective, it incurs a certain cost of service which as seen in the calculations presented earlier is directly related to the length of the grid being extended, the density of population, but equally importantly, the load/household or total load being served by the extended line. A 22 kWh/household/month consumption is significantly low which makes the cost of service very high; and is a key reason why the NEA (and distribution companies in most countries) is not interested in serving rural customers. Remoteness and inaccessibility worsen this situation.

272. However, if the grid is extended and used to not only deliver power (which is low) to the local community, but also to evacuate power being generated by the community, the incremental savings that the NEA makes per kWh in terms of avoided cost will make the investment in grid extension more attractive.

273. For example, for a grid extension of 5 km serving 1,000 households with a density of 75 households/km2, the capital cost to the NEA is NPR 22,250,000 excluding the cost of household wiring. If it were just extended into a remote community then it would deliver about 264,000 kWh annually. On the other hand if it were connected to a 100 kW MHP and the same 11 kV line was used to evacuate this power to serve other customers of the NEA, then the total power evacuated would be 581,688

Figure 27: Break-even point for grid connected 100 kW MHP

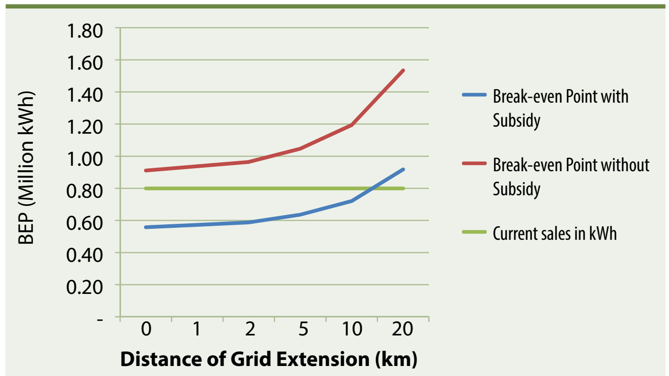
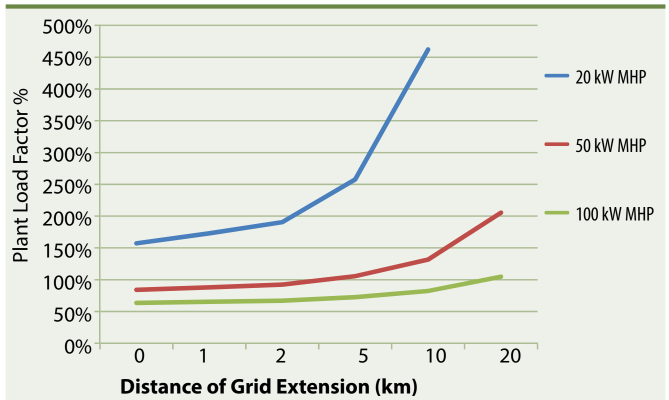


Figure 28: PLF at break-even point with subsidy for grid connected MHP at various plant capacities



kWh/year. Taking into account the cost of service for the NEA and the LUCE for power produced from the MHP with no subsidy, the savings/kWh purchased from the MHP vis-à-vis its own cost of delivery is NPR 8.00. Thus, the savings from total power evacuated from the MHP to NEA annually is NPR 4,653,500. As is evident, instead of merely extending the grid to serve rural Nepal, the NEA would be more at an advantage using the same line to purchase power from the local MHP and evacuate it to serve other nearby customers of the NEA.

274. Overall, it would be a win–win situation for both the MHP and the NEA if the grid extension leads to surplus power from the MHP being evacuated and purchased by the NEA. However from the NEA's point of view in terms of management and associated transaction costs, it may be better for it

to retire a plant by compensating the community for their investments rather than buying power from it over a period of time. The basis for compensation could be the book value of the asset plus a 16 percent RoE for the period that the MHP was in use. As against this it would have to set off the NPV of cost of power purchased from the MHP and the NPV of savings from using power from the local MHP to serve local customers. Table 38 provides an example of a financial analysis for a five-year-old 100 kW MHP that gets connected to the grid.

3.5.4. ECONOMIC ANALYSIS

275. In the preceding section, the financial viability of a grid-connected MHP was explored. In this section, the economic viability of connecting a standalone MHP and MHP mini-grids to the national grid are assessed separately. As in the financial analysis, both incremental and total economic analyses are presented in this section.

3.5.4.1. Economic costs

276. Economic costs are estimated by taking financial costs net of taxes, duties and subsidies. Labor

TABLE 37 | Input parameters for estimation of grid extension costs

Parameter	Amount	Remarks
Average domestic load demand (kWh/month/HH)	22	NEA Report 2012/13
Interconnection Cost		
Interconnection equipment including control panels, switchgear and protection (NPR*)	4,300,000	Fixed cost irrespective of MHP capacity
11 kV Distribution Line (incl. all accessories but excl. Transformer)		
Overhead ACSR (NPR/km)	1,000,000	Type of conductor depends on power to be evacuated and the distance
400 V Distribution Line (incl. all accessories but excl. Transformer)		
Overhead ACSR (NPR/km)	300,000	"Squirrel" conductor
Service wire connection and house wiring (NPR/HH)	6,000	Average cost for a rural HH (actual cost depends on number of connections/outlets in a HH – NPR 10,000 to 15,000 for urban HH)
Distribution line length km per sq. km load area	4	Taken from "Sustainability of rural energy access in developing countries", Doctoral thesis of Brijesh Mainali, 2014
Transformers for Grid Connection		
50 kVA 0.4/11 Transformer (NPR)	350,000	Nepali make
100 kVA 0.4/11 Transformer (NPR)	600,000	Nepali make
200 kVA 0.4/11 Transformer (NPR)	900,000	Nepali make
Other Parameters		
Cost of electricity generation (NPR)	6.00	
NEA system losses	23%	NEA Report 2012/13
Effective rate at distribution point (NPR)	7.79	
Life of system (Years)	40	
O&M annual cost as percent of capex	3%	
Load escalation factor	5%	
Discount factor	6%	
Debt : Equity	70: 30	
Interest rate and tenor	14%, 7 years	
Depreciation straight line method	2.5%	

*NPR 1 = US$0.0104; HH = household

costs are deflated to reflect real costs as explained in the section on economic analysis of standalone MHPs. The key capital costs of connecting an MHP to the grid depends on the interconnection equipment distance of the 11 kV extension line to connect to the grid and a 100 kV transformer. For mini-grids, it is assumed that the NEA would only permit mini-grids that are operating at 11 kV.

277. Based on the parameters specified in Table 37, the economic costs of grid extension at various distances (0, 1, 2, 5, 10, and 20 km) are presented in Table 39. Where the cost of the interconnection equipment is constant (and remains so for systems up to 500 kW in size), and the cost of the transformers where required is fairly modest, the cost of grid connection is determined mainly by the distance to the grid, i.e. by the cost of the 11 kV distribution line required.

3.5.4.2. Incremental economic benefits

278. As before, economic benefits are considered to originate entirely from the increase in PLF attributed to the following interventions: fuel savings from switching from diesel to electricity for productive end-use (as represented by an agro-processing unit, i.e. the avoided cost of diesel-based generation), and the sale of CERs based on the avoided CO_2 emissions from fuel switching. Economic benefits from grid connection vary between a standalone MHP and a mini-grid because some increase in PLF would have already been achieved in the formation of the mini-grid and thus the incremental PLF from grid connection for a mini-grid is lower than that for a standalone MHP.

279. Figure 32 presents the economic benefits arising from grid connection of various sizes of standalone MHPs at various distances of grid extension. It is assumed that starting from a 24 percent PLF for a standalone MHP, 90 percent of the remaining electricity is evacuated to the grid once the grid connection occurs.

280. Figure 33 presents the economic benefits achieved from the grid connection of a 100 kW mini-grid at various distances of grid extension. Note that the 17 percent incremental PLF achieved by the Rangkhani, Baglung mini-grid is taken to be

Figure 29: NEA cost of delivery to remote communities

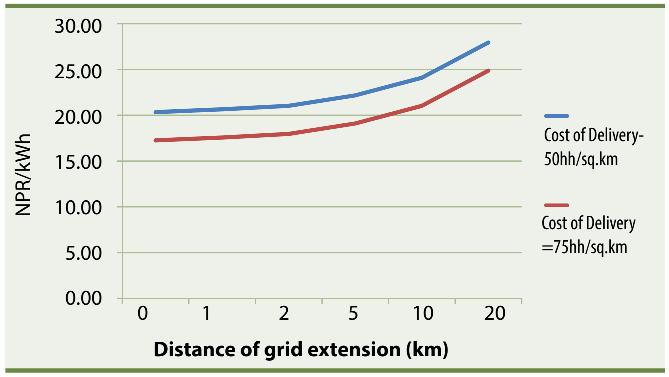


Figure 30: Cost of delivery of grid connected 100 kW MHP vs NEA grid extension

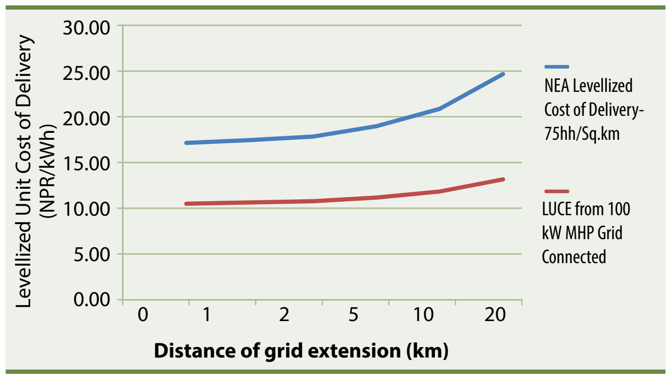


Figure 31: LUCE of subsidized MHPs vs NEA tariff and NEA cost of delivery

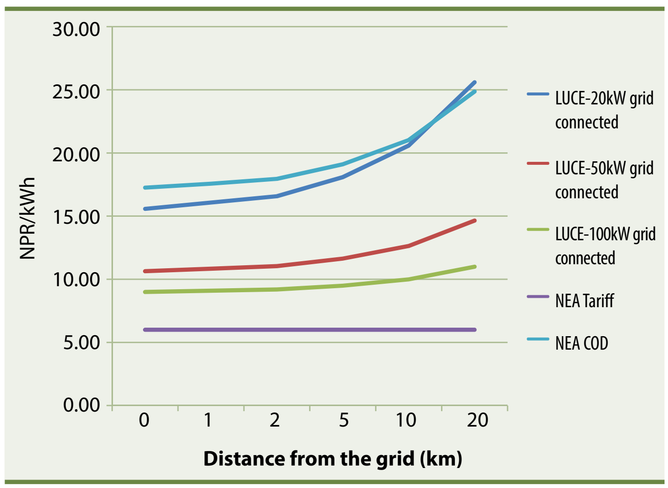


TABLE 38 | Financial analysis for a five-year-old 100 kW MHP connected to the grid

NPV of power purchased from MHP	40.28	Book value of MHP as at end of 5 years	14.08
NPV of saving for NEA by using local power to supply to local community	9.62	RoE at 16 percent for 5 years that the MHP has been operational	14.37
Net payout by NEA if MHP is connected to the grid	30.66	Total payout as compensation	28.45

NPR 1 = US$0.0104; All figures in NPR million.
Source: Based on grid connected 100 kW MHP with 0 km grid extension.

representative of the increase in PLF achieved from mini-grid formation. Thus, the incremental PLF for grid connection is deducted accordingly for the mini-grid. Due to the lower incremental PLF associated with grid connection of mini-grids, the net economic benefits are relatively lower compared to standalone MHPs of similar total capacity, but the net economic benefits are seen to be negative for a 20 kW mini-grid even at a grid connection distance of 10 km.

281. The PLF for both the standalone MHP and mini-grid are adjusted to account for the technical distribution losses (of 10 percent) within their service areas when calculating the incremental quantum of electricity generated and available for consumption upon grid connection.

282. As can be seen from these figures, there are substantial economic benefits to be realized from a grid connection because mini-grids, and especially standalone MHPs, feature relatively low capacity utilization, leaving a relatively large fraction of the generation potential available for export to the grid. Under prevailing conditions of scarcity, the evacuated electricity will displace distributed diesel generation elsewhere (perhaps in nearby market towns). Therefore, to the extent that this low cost additional generation displaces reliance on more expensive diesel generation elsewhere, the economic benefits from connecting a 100 kW system where the grid has arrived in the vicinity (0 km grid extension) ranges from about NPR 13.5 million to over NPR 18 million per annum for mini-grid and standalone MHPs, respectively. Revenue from the sale of CERs based on avoided emissions account for a relatively modest share of total economic benefits.

Figure 32: **Economic costs and benefits of grid connection**

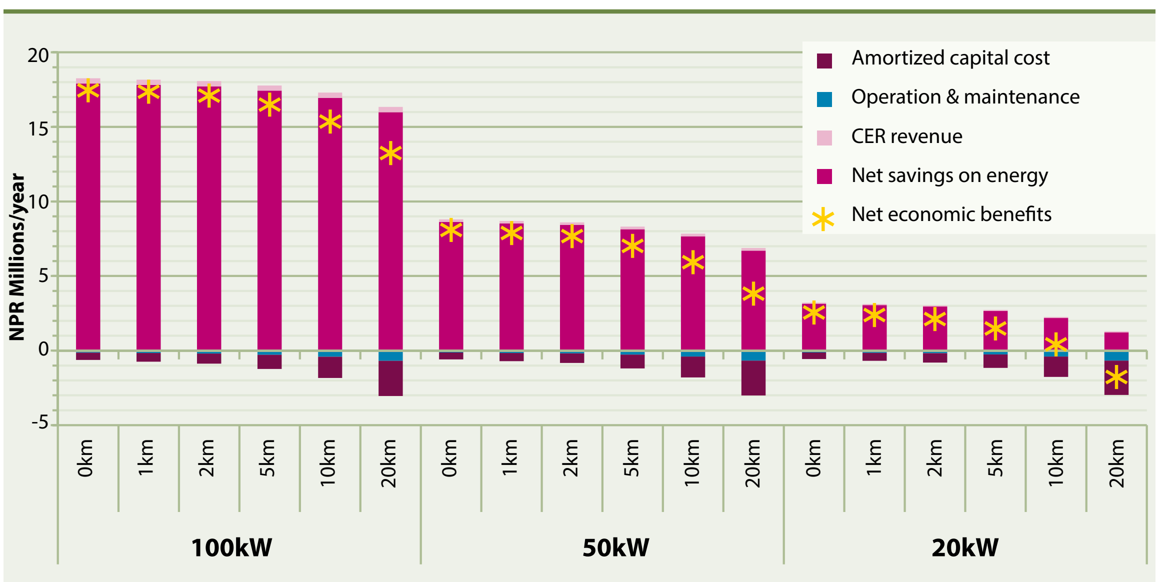
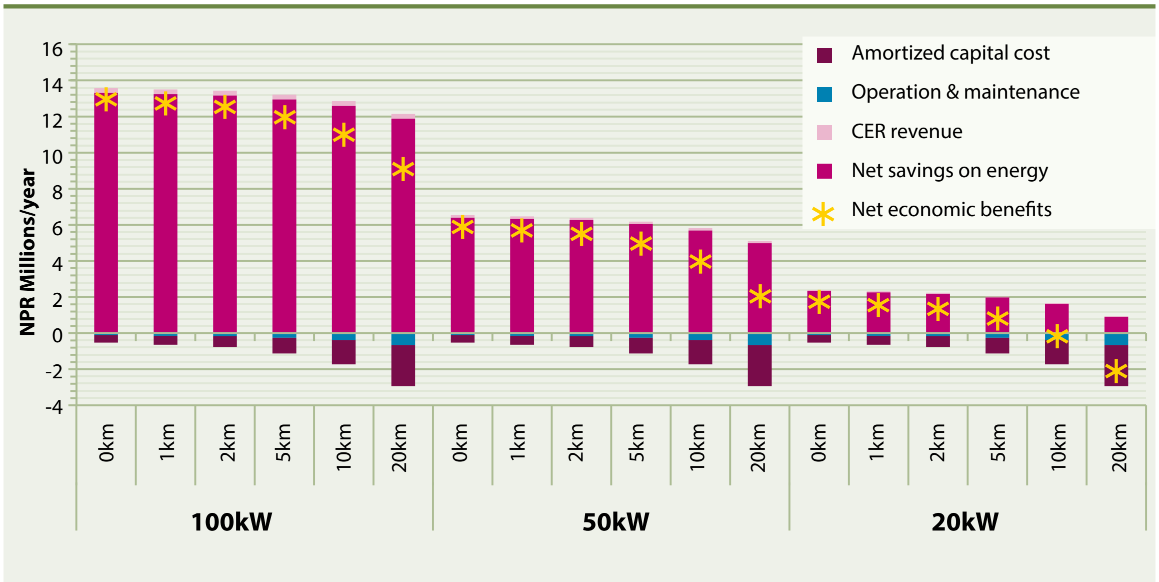


Figure 33: Economic costs and benefits of grid connection of mini-grid



3.5.4.3. Summary of incremental economic benefits and costs

283. Figure 34 displays the NPV for investments in grid interconnection for 20 kW, 50 kW and 100 kW standalone MHPs and mini-grid (for a 15-year plant life at a 6 percent discount rate). The returns are positive for all the scenarios considered up to grid extension of 10 km, except for the 20 kW mini-grids. At 20-km grid extension, neither 20 kW standalone MHPs nor 20 kW mini-grids represent a good investment opportunity. Considering the immense savings on the avoided cost of generation (from diesel) realized through grid connection, and the relatively modest cost of grid connection, the vast magnitude of the NPV for almost all the scenarios is not surprising. When the avoided cost of generation is based on distributed diesel generation, as is the case in this analysis, even a 20 kW standalone MHP delivers an NPV of more than NPR 14 million when connecting to the grid at a distance of 5 km, and the interconnection of a 100 kW standalone MHP yields an NPV of NPR 127 million even where grid connection requires a distance of 20 km.

284. Similarly, Figure 35 shows that the economic internal rate of return (EIRR) is attractive for a 100 kW standalone MHP and mini-grid even up to a grid interconnection distance of 20 km, whereas both 50 kW options clearly represent a good proposition at up to 10 km grid extension. For 20 kW systems,

TABLE 39 | Economic costs of grid extension at various distances

Breakdown of Costs	Distance of grid extension (km)					
	0	1	2	5	10	20
	Economic costs (NPR*)					
Capex with transformer	4,449,027	5,356,991	6,264,956	8,988,850	13,528,673	22,608,319
O&M with transformer	133,471	160,710	187,949	269,665	405,860	678,250
Capex without transformer	3,904,248	4,812,212	5,720,177	8,444,071	12,983,894	22,063,540
O&M without transformer	117,127	144,366	171,605	253,322	389,517	661,906

*NPR 1 = US$0.0104

Notes: O&M costs are given on an annual basis and assumed to be 3 percent of capex per annum; indicative transformer cost is for a 100 kVA 0.4/11 transformer and the actual cost may vary according to the size of the transformer required.

connection to the grid should be appealing at a distance of up to 2 km. This suggests that there are good grounds for preserving an MHP (irrespective of its size) through grid connection once the grid has reached within a few kilometers from the MHP.

285. One reason why the grid connection appears to be so evidently preferable is the enormous economic benefits obtained by exporting electricity to the grid when 90 percent of surplus capacity is assumed to be utilized for export-oriented generation, which displaces relatively expensive reliance on diesel elsewhere. As illustrated in Figure 36, all MHPs generate economic benefits well in excess of NPR 20/kWh when connected to the grid at a distance of 5 km.

286. However, the same energy scarcity that justifies the assumption of diesel generation as the avoided cost (and thus returns high economic benefits from MHP generation) also ensures that much of the electricity that could be theoretically exported to the grid cannot be evacuated in practice due to the prevalence of load shedding. Since electricity cannot be evacuated to the grid during load-shedding hours, much of the economic benefits from MHP generation cannot be realized. Figure 37 presents the NPV for each scenario when only 50 percent of the electricity available to be exported to the grid is evacuated (50 percent here approximates the weighted average of load-shedding hours over the course of a year).

Figure 34: NPV for different scenarios of grid connection

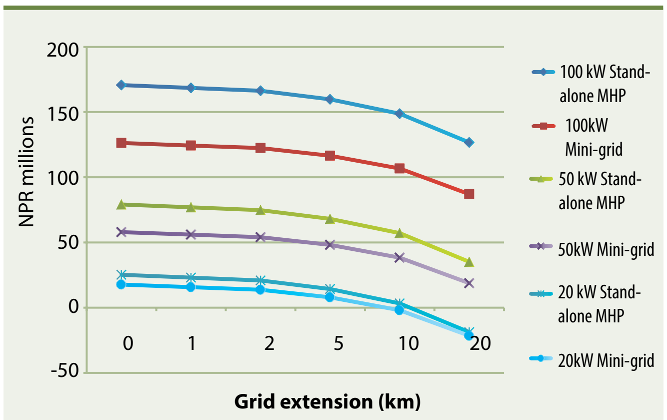
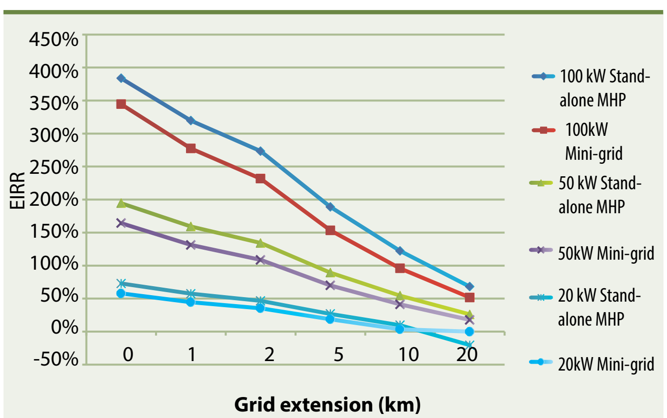


Figure 35: EIRR for different scenarios of grid connection



287. As the economic benefit from evacuation to the grid constitutes the most significant component or total economic benefit, it is to be expected that the NPV for all the scenarios would suffer. Indeed, when 50 percent of the electricity cannot be evacuated, grid connection of 20 kW MHP ceases to be an appealing option at any distance of grid extension. However, grid connection of a 100 kW MHP remains economically viable, as does grid connection of a 50 kW MHP at a distance of less than 10 km.

288. The financial analysis of grid connection in the previous section indicates that grid connection is not a financially viable endeavor at current FIT. Communities and entrepreneurs are therefore unlikely to undertake such a venture, in which case the substantial economic benefits from grid connection would be foregone. This presents a compelling argument for the application of subsidies in an efficient manner to render grid connection financially viable, and to enable significant economic benefits from grid connection to be realized.

289. However, two caveats must be taken into consideration. The economic benefits as calculated in this analysis are based on a CER price of US$7 per ton of CO_2 eq. While there is a precedent for this negotiated price in the ongoing MHP CDM project in Nepal, it may reasonably be posed whether even a fraction of this price would be available under current market conditions, and in any case, even if the CER price should recover, CER revenue will always be subject to the vagaries of the carbon market. Since CER revenue accounts for a mere 2

percent or so of the total economic benefit from grid connection, this may not be such a critical issue in any case.

290. On the other hand, the fact that the avoided cost of generation accounts for the vast majority of the economic benefits from grid connection merits closer inspection. Under current conditions of crippling generation shortage in the country, there is ample justification for the selection of distributed diesel generation as the basis for avoided cost calculation. Anecdotal evidence corroborates the proposition that unmet demand across the country is being, at least partly, satisfied through diesel generators.

291. A recent World Bank study estimates close to 200 MW of distributed diesel installed capacity generating 340 GWh per annum in Kathmandu Valley alone; this accounts for almost 8 percent of the electricity supplied across Nepal.[70] However, when and if large hydropower projects in the pipeline begin generating electricity in sufficient volumes to meet peak demand in the country – and projections state that this should happen well within the economic life of 15 years assumed for the calculations in this analysis, at least during the wet season – the relevant baseline for the avoided cost calculation will then be run-of-river hydropower generation. The economic benefits from grid connection of a 100 kW standalone MHP or mini-grid can be expected to diminish drastically once that happens.

292. It is worth asking whether grid connection of MHPs will still be economically viable once the ongoing energy crisis is resolved. Figure 38 presents the NEA's avoided cost of generating (or buying) electricity and delivering it to micro hydropower service areas of various characteristics.

293. The unit cost to NEA depends on the size of the load center (on the quantity of electricity being delivered), the distance that has to be covered to deliver the electricity (expenditure on transmission infrastructure will vary accordingly), and the population density of the service area (which affects the distribution infrastructure requirement). As can be expected, NEA incurs a higher cost to serve smaller,

Figure 36: LUBE for different scenarios of grid connection

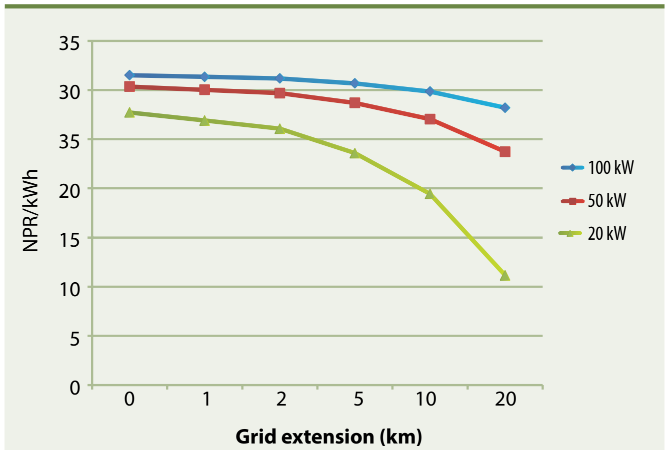
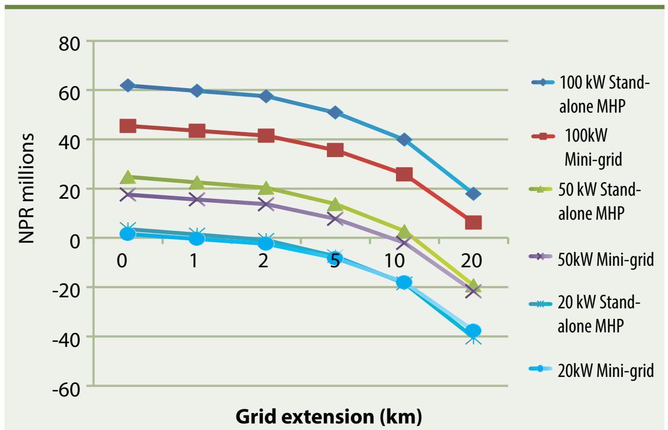


Figure 37: NPV for 50 percent evacuation to the grid after grid connection



more dispersed communities further away and a lower cost to serve a larger load center that is closer and more densely populated.

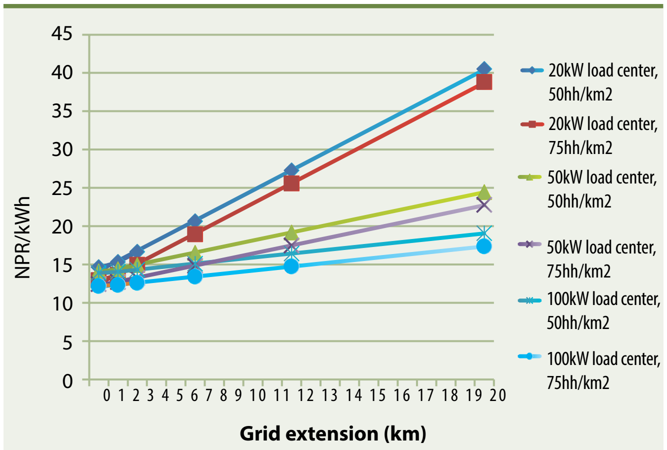
3.5.4.4. Economic analysis using avoided cost to NEA as baseline

294. Using the avoided cost to NEA as the counterfactual (the least-cost option, i.e. the cost of serving a 100 kW load center with population density of 75 households/km2, is assumed), the NPV for the various MHP scenarios were calculated. The results are presented in Figure 39.

295. Once NEA's avoided cost is taken to be the alternative, the economic benefits from connecting MHPs to the grid are much reduced, as shown in

[70] World Bank (2014): "Diesel Power Generation: Inventories and Black Carbon Emissions in Kathmandu Valley, Nepal"

Figure 38: NEA's avoided cost



Notes: 160 households served at an average load of 125 W per household = 20 kW load center; 400 households = 50 kW; 800 households = 100 kW. Avoided cost includes IPP rate for generation, system losses and transmission and distribution cost.

Figure 39: NPV for NEA's avoided cost scenario

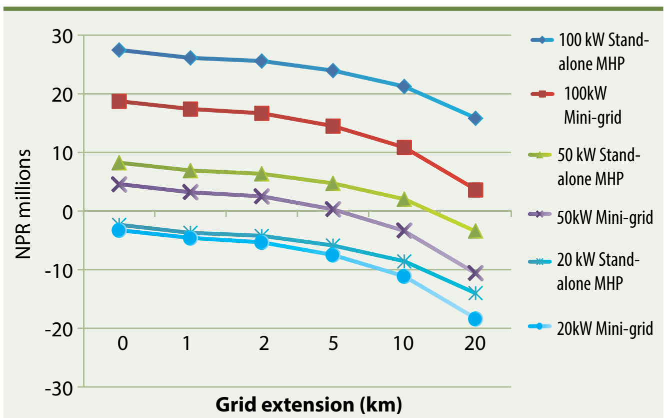


Figure 40: EIRR based on NEA's avoided cost scenario

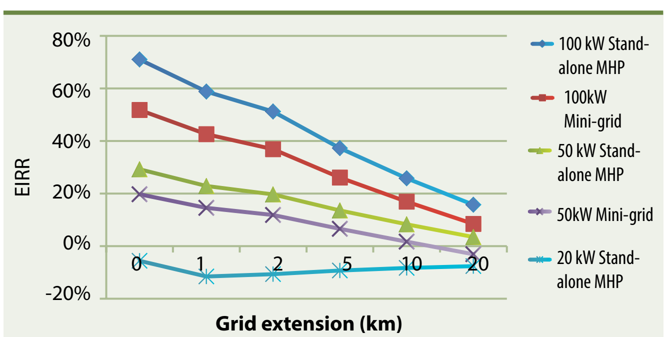


Figure 40. The EIRRs are negative at all distances of grid extension for a 20 kW MHP (so EIRRs for 20 kW standalone MHP and mini-grid are not plotted in the figure), and thus, from a societal point of view, there is no longer a case to be made for interconnection of 20 kW MHPs. Even 50 kW MHPs only make sense at close distances for grid connection. While 100 kW MHPs remain the best option for grid connection, they no longer promise the impressive level of benefits as seen in the figure. It confirms that the EIRR for grid connection of MHPs is far more modest once sufficient grid electricity can be supplied by the utility.

3.5.4.5. Full-cost economic analysis of grid-connected community MHPs

296. The incremental economic analysis of grid connection of existing MHPs and mini-grids presented in the preceding section shows that grid connection represents an attractive social investment opportunity, at least for larger MHPs that are relatively close to the grid.

297. It should be noted that the incremental cost of grid connection is relatively modest only because the initial investment in the MHP itself had already been made. Older MHPs were built to serve the nearby community, and thus grid connection constitutes an attempt to retrofit an existing asset to increase its productivity or to rescue an investment from impending obsolescence. Mini-grids are a step in that direction, and grid connection is the logical end to such an effort.

298. Today MHPs are being planned or under construction specifically with grid connection in mind, such as the Midim Khola. These MHPs tend to be larger – at least of 100 kW installed capacity. What is the economic viability of a new community MHP that will enjoy the benefits of grid connectivity from its inception? For the purpose of economic analysis, such an MHP will capture the economic benefits associated with the consumer surplus arising from households in its distribution area switching to electric lighting from kerosene lighting (its domestic load), from electricity displacing diesel generation for productive end-use in its distribution area

TABLE 40 | Economic costs and benefits of a new grid connected 100 kW MHP

Parameter	Grid connection distances (km)					
	0	1	2	5	10	20
Consumer surplus from lighting	13.17	13.17	13.17	13.17	13.17	13.17
Net savings on energy	18.50	18.41	18.31	18.02	17.54	16.58
CER revenue	0.49	0.49	0.49	0.49	0.49	0.49
Total benefits	32.16	32.06	31.97	31.68	31.20	30.24
Operation & maintenance	1.18	1.21	1.24	1.32	1.45	1.73
Amortized capital cost*	4.05	4.15	4.24	4.52	4.99	5.92
Total costs	5.23	5.36	5.48	5.84	6.44	7.65

NPR 1 = US$0.0104; All figures in NPR million.
*For a 15-year plant life at a 6 percent discount rate.

(the commercial load), from the generation of electricity for export to the grid, and from the carbon revenue based on avoided emissions attributed to its existence. In terms of costs, the capital cost and operations and maintenance cost of the generation asset itself as well as the capital cost and operations and maintenance cost of grid connection will have to be included. Table 40 displays the full economic costs and benefits of a 100 kW MHP when it is able to evacuate its entire surplus power to the grid.

299. As substantial economic benefits accrue from the operation of a standalone MHP and from the grid connection of such an MHP, a new MHP that is connected to the grid realizes the benefits from both these streams. The economic benefits from a new grid-connected MHP are therefore vast. As discussed in preceding sections, carbon revenue is a modest part of total economic benefits and thus has a negligible impact on the determination of economic viability.

300. However, a new MHP will not be able to evacuate as much electricity as it may wish to due to the prevalence of load shedding, as discussed in the preceding sections. Figure 41 and Figure 42 illustrate the NPV and EIRR respectively of new grid-connected MHPs that can only evacuate half of the surplus power they could generate. This represents the near term scenario.

301. Once there is widespread availability of NEA grid electricity, the economic benefit per unit can be expected to be substantially curtailed since the avoided cost will be in hydro-electricity rather than diesel, but it will be possible to evacuate all of the surplus power generated by the MHP so economic benefits can be realized from a greater number of units. This represents the longer-term scenario and is also illustrated in these figures.

302. On a full cost basis, 100 kW grid-connected MHPs are found to be attractive investments at grid extension distances up to 20 km both in the near and long term, as are 50 kW MHPs, albeit to a lesser extent. However, 20 kW MHPs only represent a good investment from the societal point of view up to a grid extension distance of 5 km.

303. The financial analysis in the earlier sub-section indicates that grid-connected MHPs are not financially viable (even with a 50 percent subsidy on all capital costs, i.e. for the generation asset plus the interconnection costs) at current tariffs, but the magnitude of the economic benefits that can be captured from grid-connected MHPs calls for action both from the Government and micro hydropower communities to ensure that these benefits are realized.

3.5.5. INSTITUTIONAL PERFORMANCE

304. Currently, there are no MHPs that are grid connected and therefore, there is no experience of institutional performance of MHPs in this regard. When the national grid arrives in the distribution area of an MHP, it can be interfaced with the national grid in various configurations as follows:

- **Option 1:** Connect the MHP generator to the national grid and allow the national grid to take over the local distribution services.

Figure 41: Net present value for new grid-connected MHP

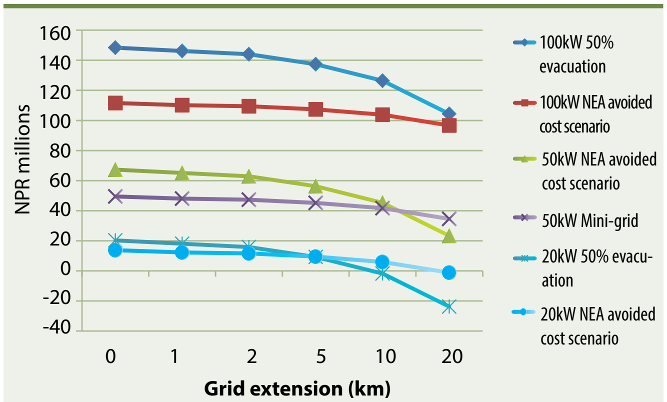
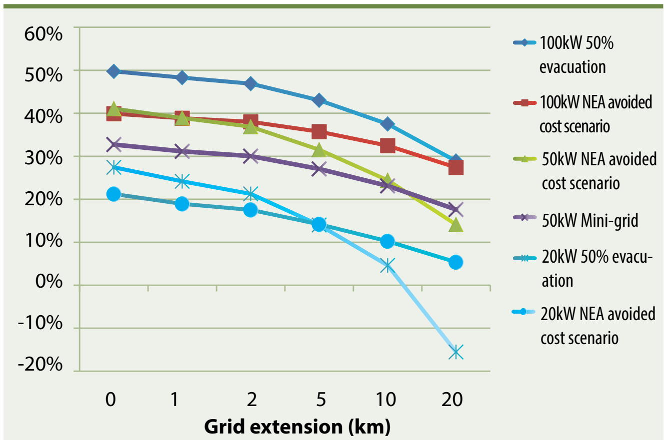


Figure 42: EIRR for new grid-connected MHP



305. This is the model being preferred by the NEA. MHP is treated as an IPP and all power supplied by the MHP is fed into the grid. Local customers get electricity from the NEA at normal tariffs. However, in the event of load shedding, customers do not get served by the MHP. As an IPP the MHFG would seek to maximize profits by selling only to the grid. Furthermore, with the MHFG not serving the community, the MHP could be taken over by private investors. The NEA also does not benefit since it would also be responsible for local distribution and collection of electricity bills in a remote location.

306. From an AEPC point of view, the capital subsidy given to the MHP is not helping to serve the local community, even during events of load shedding by the grid. Therefore, it would have to put in place a mechanism to recover the capital subsidy given to the MHP from the revenues earned by the MHP by selling power to the grid.[71]

307. From an NEA point of view, if an MHP is treated as an IPP, it would have to permit even private MHPs to be set up exclusively for grid connection. Since the policy for allowing MHPs to connect to the grid is being proposed to avoid community investments from being stranded rather than to help the NEA tide over the peak deficit crisis, it does not make sense for the NEA to buy power from MHPs being set up as IPPs. Therefore, the policy should clearly direct the NEA to allow grid connection of MHPs only if they are community owned and set up in the first place to serve them.

- **Option 2:** Connect the MHP generator and the local distribution grid to the national grid with provisions for providing power to the local community through the MHP generator and the local distribution grid during load shedding or outages on the national grid.

308. This is the preferred option by the AEPC and the authors of this report. MHP sells all its power to the NEA at PPA rates as an IPP and buys at bulk NEA rates for communities as for CBRE. This would allow the community to access electricity at NEA rates, which is highly subsidized. NEA gains by not having to manage the distribution network. The MHFG being still responsible to the community has to continue managing the distribution system and coordinate with the NEA. In addition, the NEA gets access to locally generated power that is cheaper than its cost of delivery as described in the preceding section. The MHP as an IPP gets access to a higher PLF through connecting to the grid and can maximize its output and thereby lower its LUCE substantially.

309. However, the NEA has indicated that it is not in favor of this option since it does not want to treat MHP customers on par with CBRE customers. The NEA is apparently mulling over charging a commercial bulk tariff rate that is slightly higher than its IPP-PPA rate if power is supplied to the local community through the MHFG. This thinking runs counter to

[71] In the Ramgarh MHP in Uttarakhand, India, which is a 100 kW MHP connected to the grid since 2005, 75 percent of revenue from sale to the grid goes to Uttarakhand Renewable Energy Development Agency (UREDA) since it had provided a 75 percent subsidy in setting up the MHP. Further, the MHP supplies power to the local community during load shedding by the grid. The MHP management is responsible for both supply of power to the grid, as well as acting as a franchise for the grid in managing the distribution network.

logic. By supplying through the MHFG and making them responsible for managing the distribution, the NEA reduces its costs of service.

310. Furthermore, since power delivered by the NEA is costlier than power purchased from the local MHP, it is better for the NEA to let the MHP supply as much power as possible to the local community, but charge the community normal NEA tariff. This will ensure that its losses in supplying power to a remote community are considerably reduced.

- **Option 3:** Shut down the MHP generator and local grid and have the customers switch over to the national grid.

311. For reasons discussed earlier, this is an option that all stakeholders are trying to avoid by ensuring the formulation of a policy for grid connection of community owned MHPs that are currently serving the local community.

312. If the PPA FIT were set at a level adequate to cover the MHPs costs with a reasonable RoE (this is the same as the LUCE) then it would be profitable for the MHP. Therefore, institutionally, the organization managing the MHP should be on a sound footing legally and in terms of representing the actual owners, i.e. the community. There should be an appropriate mechanism to channel the profits into the community either by way of dividends to each member household or for taking up community level development works or a combination of both.

313. The AEPC would need to put in place a process to ensure that the level of organizational development of the MHFG is adequate and proper business processes that aid transparency, equity and good governance are in place while the MHP gets connected to the grid and moves on to become a more business like organization.

314. In addition, given the sensitivity of the MHP's financial performance to grid availability for evacuation of power to the grid, "deemed generation" also referred to as "take or pay" status should be included as a clause in the PPA.

Figure 43: Configuration of Option 1

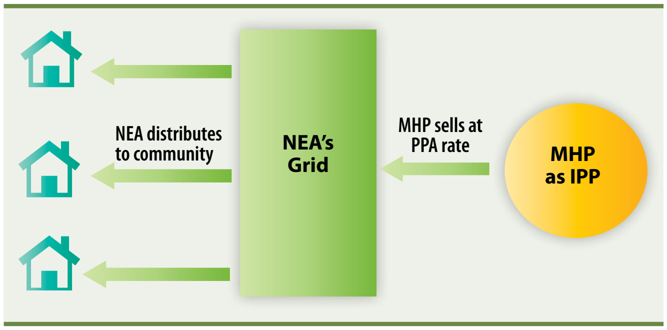


Figure 44: Configuration of Option 2

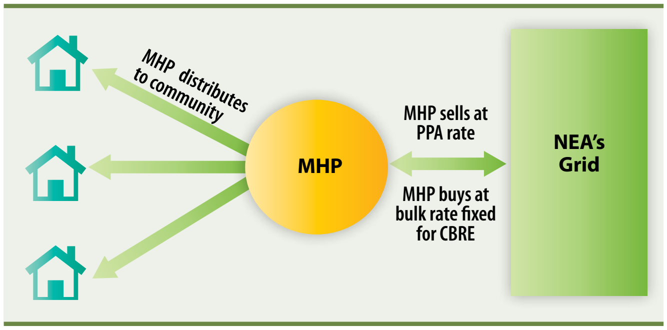
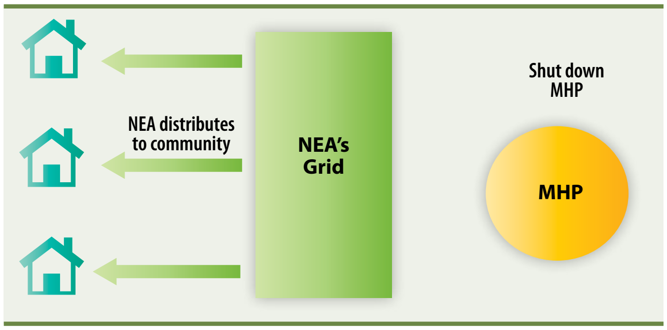


Figure 45: Configuration of Option 3



3.5.5.1. International practices in grid connection of MHP

315. International practices indicate that MHPs and RETs in general benefit from promulgation of acts that ensure standardization of grid connection (see Box 5). Comparing different electrification options on the basis of LUCE (NPR/kWh) can help chose the best alternative and even compare with consumer retail price of electricity (NPR/kWh) to set the appropriate FIT.

316. Passing laws that ensure discounted lending for grid connection of previously isolated systems can help expedite the process considerably. Integration of technical standardizations, FITs, open access to grid and financial incentives for grid connection under "One Window Services" can help simplify the process for RETs interested in grid connection. This study presents a clear methodology for determining FIT for grid-connected MHPs. Therefore, NEA, AEPC and MHFGs can use this methodology as a guide to determine FIT for grid-connected MHPs and incorporate them into the standardized documents.

Box 5: LESSONS FROM RET GRID CONNECTION PRACTICES AROUND THE WORLD

Germany: Renewable Energy Sources Act (2004) prioritizes as well as outlines procedures for connecting RETs to the national grid. It sets standards for purchase, transmission, and payment for such electricity.

China: Renewable Energy Law (2006) guarantees financial incentives, such as discounted lending and tax preferences for RETs.

Denmark: Feed-In-Tariff for RETs set at 70–85 percent of consumer retail price of electricity and open access to utility grid guaranteed under "One Window Service".

Australia: Renewable Energy Act (2000) includes a framework to create Renewable Energy Certificates by RETs and then sell to electric utilities to meet their renewable energy purchase obligations.

Tanzania: Framework being developed under the Electricity Act (2008) includes standard documents, such as "Standardized Power Purchase Agreement" and "Standard Tariff Methodology" applicable between renewable energy projects with capacity between 100 kW to 10 MW and buyers such as the national grid or local isolated grids.

See Annex 10 for more details on international practices in grid connection.

317. Furthermore, a framework for creation and trading of Renewable Energy Certificates can ensure fair promotion of RETs including MHPs by requiring large hydropower projects to meet renewable energy purchase obligations. It must be noted that hydropower projects with capacity more than 20 MW are not considered renewable energy projects. If these international best practices are internalized under a "One Window Service" by the AEPC, grid connection of MHPs can be streamlined into a quick and hassle-free procedure.

318. Although, there are examples from other countries that are ahead in grid-connected MHPs and RETs, in Asia and specifically in the Himalayan region, Nepal is the forerunner in community managed off-grid micro hydropower systems. It has the largest number of off-grid MHPs installed and successfully operated by rural communities. A central government body coordinating the micro hydropower sector and administrating subsidy along with private sector involvement in design, manufacturing and installation, and the communities' ability to mobilize themselves and manage the plants post installation has become an unique and successful model.

319. Other countries from South Asian Association for Regional Cooperation (SAARC) interested in implementing national level micro hydropower programs have been drawing upon Nepal's experience in this sector. In order to formalize such exchange of experience, in 2010 the AEPC in collaboration with USAID South Asia Regional Initiative for Energy (USAID/SARI Energy) established a Regional Centre of Excellence for Micro Hydro (RCEMH). The Centre showcases and transfers know-how gained by the AEPC and its supporting organizations and partners.

04

Findings, Recommendations and the Way Forward

4.1 STANDALONE MHP

4.1.1. TECHNICAL FINDINGS AND RECOMMENDATIONS

4.1.1.1. Scale-up MHPs to reach more off-grid communities

320. MHPs are technically robust and help off-grid rural communities in Nepal gain access to electricity. Local communities have demonstrated adequate capabilities to operate and maintain MHPs in remote locations. Furthermore, where there are steep perennial streams in the vicinity, an MHP is the least-cost option for rural community electrification. Therefore, on the basis of technological performance, MHPs should be scaled up to reach out to more communities that are currently not being served by the national grid.

4.1.1.2 Make metering mandatory to improve energy efficiency

321. MHPs are currently being built to cater to peak load, which mostly comprises lighting. Often, these MHPs are unable to cater to increase in peak demand arising from increase in the number of households and/or increase in demand within each household. Use of advanced lighting technologies such as CFLs and light emitting diodes (LEDs) will bring down household lighting loads without compromising on lighting quality. However, since most micro hydropower supplied households are not metered, extensive use of power-based tariff is discouraging energy conservation. Therefore, energy-based tariff should be enforced through metering which will provide adequate incentives to users to make more efficient use of electricity. This would in turn help lower the peak demand and allow the same MHP to serve more households.

4.1.1.3 Build grid-compatible MHPs

322. Once the national grid arrives in an MHP's service area, grid connection is unequivocally the next step forward. Therefore, while implementing new standalone MHPs, especially MHPs larger than 50 kW,[72] they should be designed to be grid compatible. This requires all new MHPs to have a distribution network that meets NEA standards. This would ensure that the MHP's distribution network gets grid connected in the future. Furthermore, mandatory metering of MHPs enables their existing customers to make the transition to NEA's energy-based tariff system smoothly. The NEA is also able to accept these customers without having to introduce a metering system.

4.1.1.4. Strengthen quality assurance during design, manufacturing and installation

323. The robust technical performance of MHPs is a testament to the excellent technical capabilities of the MHP industry in Nepal. However, as mentioned earlier with new manufacturers and installers coming in and experienced ones leaving the industry, the quality of manufactured components and execution of civil works has deteriorated. Therefore, the quality assurance system during design, manufacturing and installation should be strengthened. During the design phase, the focus should be on improving the quality of the feasibility study reports such that they truly reflect site conditions. The AEPC should carry out a three-stage inspection process during material, in-process and pre-shipment stages to ensure that the quality of the components delivered at site is as per design and material specifications.[73] Similarly, supervision and quality assurance of civil structures, which is usually executed by the community, should

[72] MHPs of 50 kW and above should be built for grid connectivity. For smaller MHPs, an intermediate step for the formation of a mini-grid has to be carefully examined.

[73] Use of mild steel in place of stainless steel for making jet nozzles and using copper coated aluminium plates for earthing were some of the quality issues mentioned during our discussions with RSC and manufacturers

be strengthened to help curb problems such as undersized settling basins leading to frequent damage of turbine runner blades. Quality assurance will prevent unwarranted downtime as well as unexpected future costs of repairs for the MHP.

4.1.1.5. Create a network of local repair service providers

324. Remoteness of MHPs from manufacturers and installers who also provide after-sales services often leads to prolonged downtimes and high costs of repairs. Given the large installed base of MHPs especially in central and eastern Nepal, the AEPC should identify, encourage and nurture local workshops[74] to provide last mile after-sales services. In collaboration with the NMHDA, the AEPC should train local entrepreneurs to cultivate skills and expertise in repairing MHPs.

4.1.2. FINANCIAL AND ECONOMIC FINDINGS AND RECOMMENDATIONS

4.1.2.1. Continue subsidy support to ensure delivery of economic benefits

325. Economic benefits that can be attributed to MHPs especially due to consumer surplus from electric lighting are immense. Rural electrification through MHP returns economic benefits approximately three times larger than the investment and operating costs. Although the economic benefits of an MHP are far greater than the economic costs, MHPs are not financially viable in the conventional sense. Therefore, subsidy should be continued to support the delivery of electricity through MHPs.

4.1.2.2. Prioritize MHP as the preferred RET to deliver off-grid electricity

326. Other than MHPs, SPVs are the most extensively used technology to deliver access to electricity to off-grid locations in Nepal. Diesel generators are another alternative but rarely used for electrification because of high operating costs. Analysis shows that for delivering the same level of service as of a typical MHP in rural Nepal, diesel and SPV-based solutions remain more than twice as expensive. Therefore, from a policy point of view, MHPs should be the first choice to deliver off-grid electrification where they are technically feasible.

4.1.2.3. View MHPs as social enterprises

327. MHPs are run as social enterprises and are not financially viable in the conventional sense, even with subsidy. Most of them make modest profits operationally but have no savings to pay for major repairs. The main reasons for poor finances are very low PLF and tariffs that are designed to just recover funds for salaries and routine repair and maintenance.[75] When large repairs are necessary, MHFGs mobilize funds from the community, which becomes possible due to the strong leadership of the MHFGs and the active participation of the community. These are key contributing factors for operating MHPs over a long period of time despite being financially unviable. However, MHPs will not be attractive to private investors who look for attractive RoIs. Therefore, MHPs need to be viewed as social enterprises similar to rural roads or schools and not from a conventional financial analysis perspective, especially when formulating or updating policies.

4.1.2.4. Build capacity of MHFGs in tariff setting

328. The capacity of MHFGs and the user community should be built to adopt energy-based metered tariff rather than power-based non-metered tariff. In addition, they should be trained in setting tariffs such that revenues are adequate to cover operating costs including salaries, loan payments, as well as repair and maintenance.

4.1.2.5. Increase access to finance and educate lenders on operational sustainability of MHPs

329. Typically, the community mobilizes 50 percent of the total project cost to set up an MHP and the remaining is provided through the AEPC as subsidy. Mobilization of funds from the community to achieve financial closure is a major bottleneck in MHP implementation. Access to finance could significantly shorten this time but banks and financial institutions (BFIs) are usually reluctant to lend to these projects citing reasons of low profitability and uncertainty of institutional arrangements.[76] On the other hand, communities are reluctant to borrow from BFIs due to cumbersome procedures and high interest rates. Therefore, the AEPC needs to educate BFIs on the operational sustainability and good track record of MHFGs. The AEPC can help reduce interest costs for these communities by parking a portion of its funds with selected banks. With higher loan amounts, MHFGs will also be compelled to increase consumer tariff to be able to payback such loans and the interest.

74 Especially, units such as grill works, electricians, etc.

75 Where there is a loan, tariffs are set higher initially to pay off the loan and then reduced after that.

76 MHFGs are not legal entities.

4.1.2.6. Reduce costs by benchmarking and standardization

330. To tackle the ever-increasing cost of MHPs, the AEPC in collaboration with NMHDA should institute a thorough engineering-based review of the manufacturing process and costing of MHP to establish cost benchmarks. Benchmarking should be followed by standardization of MHP components as opposed to the total customization that prevails today for manufactured items. These two measures will help reduce costs. Moreover, specialization should be encouraged subject to the volume of business amongst manufacturers and alternative technologies such as "pumps as turbines" [77] should be tried out for further cost reduction.

4.1.3. INSTITUTIONAL FINDINGS AND RECOMMENDATIONS

4.1.3.1. Support MHFGs to become legal entities

331. The institutional architecture to implement MHPs is very robust and well tested. MHFG as an institution is performing adequately and represents the community well. It is able to raise significant funds from the community for equity and major repairs. However, efforts must be made post-installation to help MHFGs transition into a formally registered entity (company, cooperative or NGO). By adopting a more business-like approach, the MHFG will become capable to prepare business plans, enter into agreements with the NEA and maintain books of accounts. At the same time, it is equally important to ensure that the MHFGs retain the spirit of "social enterprise" as they move towards a more business-like approach.

4.1.3.2. Increase the institutional footprint of AEPC

332. Quality assurance and monitoring of the performance of installers and RSCs through concurrent and regular post-installation surveys are key areas that need more attention from the AEPC. Therefore, the AEPC should set up regional offices especially in areas of expected growth in community electrification and start a procedure of devolving the decision-making process. Currently, there are only nine RSCs, each covering several districts for not only promoting MHPs, but also the entire range of RETs that the AEPC supports. With the advent of mini-grids and grid connectivity, the RSC's workload will be further escalated. Therefore, more RSCs should be brought on board to support scaling up of MHPs. Additionally, the technical capacity of RSCs to provide oversight to project execution should be enhanced through exchange of knowledge and experiences, collective planning of strategies, and use of better equipment.[78] Furthermore, the AEPC should disqualify service providers who do not meet accepted standards of performance. This will help improve service delivery as well as increase business volume for service providers that are performing well.

4.1.3.3. Reorient MHP planning to aggregate demand and optimize site potential

333. AEPC's MHP program is demand driven such that the project cycle starts when a community makes a request to the RSC to help it set up an MHP. Because the current unit of planning for an MHP is a VDC/Ward, this practice often leads to development of several small MHPs in the same area serving adjacent communities. Each plant is built such that it is adequate to meet the demands of the community proposing the MHP. Analysis shows that smaller plants are usually less viable even operationally and also cost more to set up than larger plants. Furthermore, the current process of MHP planning leads to underutilization of the hydropower potential of the site. Therefore, the focus of planning for MHPs should be changed from merely meeting the current power requirements of the community to optimizing site potential. When the pre-feasibility study of an MHP is carried out by the RSC/DEECCS to determine site capacity, they should simultaneously explore whether there are more load centers that are not served in the vicinity and if a single large MHP can serve the combined load better.

4.1.3.4. Strengthen the pre-qualification process of service providers

334. The current pre-qualification process is based on capability statements of DFS consultants, installers and manufacturers as well as verification visits to the manufacturing premises. In addition to these measures, a more systematic and concurrent quality assurance and post-installation survey should be adopted to monitor performance over an extended period of time and then rank such companies. Similar to quality assurance mechanisms for the biogas program, AEPC should put in place a comprehensive post-installation survey of MHPs and monitor a sample of projects. The sample could be relatively higher during the first year after commissioning and

[77] AEPC could organize exposure trips to India where PAT has been in use for more than a decade.

[78] Currently, RSCs only provide technical oversight based on visual observation during project execution. They have no tools to provide any diagnostic support.

then gradually tapered off to zero by the 5th year. Thus, a new set of samples would be added from MHPs installed every year while a few that have been monitored for five years would be dropped out of the sampling plan.

4.1.3.5. Formulate and update relevant Acts in RET promotion

335. Although many policies to upscale RETs have been put in place, full-fledged implementation of such policies is not possible without promulgating the corresponding acts. Therefore, these acts (Rural Energy Act, Water Resources Act and Electricity Act) need to be either formulated or updated to support smoother implementation of the policy. Furthermore, important acts related to renewable energy development (Feed-In-Tariff Act and Alternative Energy Promotion Board Act) should be approved by the Parliament.

4.1.3.6. Support the micro hydropower industry to expand business into mini hydropower and low-head MHPs

336. Due to the low volume of business, large and experienced manufacturers are losing interest in the micro hydropower sector. Furthermore, analysis shows that smaller MHPs are unsustainable even operationally. Therefore, the AEPC should collaborate with the NMHDA to build the capacity of the industry to manufacture and install mini hydropower plants. Additionally, it should also identify appropriate technology to harness the hydropower potential of low-head and high-flow rivers that are prevalent in the lower hills and the Terai belt of Nepal. Currently, entrepreneurs in India are demonstrating an "ultra low-head MHP"[79] on a quasi-commercial basis with support from UNIDO and technology from Japan. If this technology can be introduced in Nepal, it may open up a whole new area of business for the micro hydropower sector.

4.2. MHP MINI-GRID

4.2.1. TECHNICAL FINDINGS AND RECOMMENDATIONS

4.2.1.1. Promote higher capacity end-uses to ensure increase in PLF

337. The experience from the Baglung mini-grid clearly demonstrates that mini-grid systems are technically viable as well as reliable. In a mini-grid cluster, when there are some MHPs with a power deficit and others with surplus power, the PLF can increase significantly, and the mini-grid should be able to serve local demand better (at least in the deficit areas) than standalone plants. However, higher surplus during peak hours is very unlikely since most MHPs are overloaded in this period, and therefore the increase in PLF is heavily dependent on greater utilization of off-peak power. The number of productive end-uses in the area is not likely to increase simply because of the establishment of the mini-grid. Additionally, increase in commercial demand is also dependent on the local economy and market conditions, such as availability of raw materials, entrepreneurs, and infrastructure (e.g. roads). Nevertheless, the Baglung mini-grid experience indicates that with mini-grid systems, commercial demand can increase as the overall capacity of the system will be higher than the individual plants, enabling higher capacity end-uses that were not possible before.

4.2.2. FINANCIAL AND ECONOMIC FINDINGS AND RECOMMENDATIONS

4.2.2.1. Analyze site conditions to determine financial and economic viability

338. Financially, mini-grids are not attractive since the cost of interconnection among MHPs is very high and analysis shows that even for an optimistic scenario of PLF doubling after the formation of the mini-grid does not make it viable. Furthermore, the capital expenditure of a mini-grid is entirely site specific and requires a careful consideration of such issues when the investment decision is made. Similarly, the economic viability of a mini-grid depends largely on the increase in PLF, amount of peak or off-peak electricity available, and utilization of such electricity to replace diesel used for commercial purposes. Although unlikely, if there is any surplus during peak hours, then the economic benefits are substantially higher compared to off-peak power. Therefore, mini-grids should be assessed on a site-by-site basis for economic viability.

4.2.2.2. Promote a larger capacity MHP rather than a new mini-grid

339. Since the cost of interconnecting MHPs is large and unrelated to their capacities,[80] it would be more efficient to deliver power to a larger set of consumers from a single large micro/mini/small hydropower plant rather than putting up several smaller MHPs and trying to interconnect them later to form a mini-grid. For now, all decisions pertaining to investments in mini-grids should be made centrally by the AEPC. Furthermore, for new standalone MHPs,

[79] Works with 1–3 m heads

the pre-feasibility process should be modified to explore possibilities of a larger plant that serves a larger distribution area rather than supporting several smaller plants, which would be interconnected later to form a mini-grid.

4.2.3. INSTITUTIONAL FINDINGS AND RECOMMENDATIONS

4.2.3.1. Give preference to larger plants spread across multiple communities than mini-grids

340. When a community initiates a single MHP that is later interconnected to other MHPs to form a mini-grid, problems in terms of identity and ownership may arise. The community that previously had been displaying a strong sense of pride and ownership in their community-owned MHP cannot relate in a similar manner to a larger mini-grid. This dual identity can lead to conflicts and put a huge strain on the leadership of the mini-grid.[81] On the other hand if the community were to start off as a larger micro/mini/small hydropower plant with a transmission and distribution network spread across several wards/VDCs, then these issues of identity and ownership are less likely to arise later. However, the process of mobilizing and organizing a community that is spread across several VDCs is not easy. The success of community-managed distribution grids spanning over several VDCs (e.g. South Lalitpur Rural Electrification Cooperative and Lamjung Electricity Users Association) offers hope and direction in this regard.

4.2.3.2 Ensure market availability for off-peak power for mini-grid

341. The necessity to form a mini-grid stemmed from NEA's preference of only permitting MHPs larger than 100 kW to connect to the grid. However, after the recent decision of NEA's Board of Directors to permit MHPs of any size to connect to the grid, this rationale for forming a mini-grid is not relevant any more. Therefore, a mini-grid should be considered if there are guaranteed consumers for off-peak power from an MHP throughout the year.

4.3. MHP GRID CONNECTION

4.3.1. TECHNICAL FINDINGS AND RECOMMENDATIONS

4.3.1.1. Prepare the community for grid connection

342. Given that the grid will soon reach most micro hydropower sites in the mid-hills of Nepal, the AEPC should ensure that all new MHPs have a grid-compatible distribution system and that end-users are metered. Operators of MHPs do not receive enough technical training, and therefore, are often uninformed about operational and safety issues that arise in the context of a national grid connection. It is recommended that the community's technical and managerial capabilities be improved to get them "grid ready" through appropriate training programs.

4.3.1.2. Install appropriate safety measures to protect against unintentional islanding

343. Unintentional islanding is a potentially hazardous condition that occurs when the grid-connected MHP fails to properly shut down during a grid disturbance. It presents a hazard to line workers who might assume that the lines are not energized during a failure of the central grid. It also denies central control over power quality and can damage utility or customer equipment at the time of reconnection if the process is not properly coordinated. Islanding can be detected by measuring over-/under-frequency, over-/under-voltage, rate of change of frequency, voltage phase jump, and reverse reactive power flow. With appropriate safety and control mechanisms, intentional islanding should be used to provide reliable service to consumers of the grid-connected MHP when there is load shedding on the national grid. Moreover, a national grid connection at 400 V level should be avoided as this results in high transmission losses and also gives rise to safety issues, such as feedback into the grid. Thus, grid connection should be done at the 11 kV level, which is technically feasible and also addresses safety concerns.

4.3.2. FINANCIAL AND ECONOMIC FINDINGS AND RECOMMENDATIONS

4.3.2.1 NEA should give preference to power from MHPs

344. At 90 percent PLF and assuming all surplus power from an MHP is sold to the grid, the LUCE of an MHP in the rural hills of Nepal is cheaper than delivering the same power by extending the national grid. Additionally, economic analysis shows that delivering electricity through an MHP is cheaper than delivering electricity through NEA's grid. Therefore, for every unit of electrical energy purchased by the NEA from an MHP and sold in the rural hills, NEA incurs a lower cost. For example, the cost of delivery through NEA's grid in the rural hills is NPR 17–25/kWh depending on the distance of grid extension. On the other hand, it costs just NPR 9–15/kWh for a 100 kW MHP to deliver that energy. The NEA has agreed to offer weighted average FIT of NPR

[80] The interconnection cost is the same for a 10 kW or a 100 kW MHP.

[81] The first mini-grid at Rangkhani is grappling with this situation

6/kWh[82] for MHPs; the same PPA rates that it offers to SHPs with capacities up to 25 MW. Therefore, it makes financial sense for NEA to buy power from MHPs. The AEPC should continue to determine FIT for hydropower projects separately, since the current FIT is considerably lower than NEA's cost of delivery and unlike MHPs, SHPs enjoy substantial scales of economy.[83]

4.3.2.2. Base grid connection of MHPs on distance to grid and plant size

345. Based on incremental analysis, the financial and economic performance of a grid-connected MHP is attractive. However, as the plant capacity decreases and distance to the grid increases, incremental viability reduces. Furthermore, if only 50 percent of the surplus power from an MHP can be evacuated to the grid due to non-availability[84] of the grid, the PLF of the MHP falls drastically making grid connectivity unviable. In general, grid connection of an MHP with capacity less than 20 kW was not found to be viable based on incremental analysis. Therefore, it is necessary to undertake incremental financial analysis before connecting an MHP to the grid. On an economic basis too, when surplus power from an MHP is used to replace NEA's grid power rather than diesel-based generation, then smaller plants tend to become unviable.

4.3.2.3. Encourage banks and financial institutions to finance grid connection of MHPs

346. Loans financing for grid connection of larger MHPs could be a potential opportunity for BFIs. Even at the current FIT rates announced by the NEA, incremental analysis shows that larger plants are viable. Furthermore, given that an MHP would have been in operation for a while before the grid arrives, lenders can assess the institutional stability and risks better to arrive at an informed decision on lending. The NEA as a buyer of power is a government-backed institution and therefore the revenue risk is further reduced from the perspective of the BFIs. Therefore, the AEPC should facilitate the process by creating greater awareness about financing the grid connection of MHPs among BFIs.

4.3.2.4. Facilitate access to low-cost loans rather than providing capital subsidy

347. High interest rates deter MHPs from approaching banks for financing; therefore, it is likely that MHFGs would expect the AEPC to provide a capital subsidy to finance a grid connection. However, given the financial viability of larger MHPs on an incremental basis, the AEPC should support MHFGs by providing credit facilities, where its funds are "on-lent" by BFIs with a minimal interest spread (as well as risk guarantees) for grid connection of MHPs. Availability of low interest loans would make grid connection of MHPs even more attractive.

4.3.2.5. Ensure availability of grid for power evacuation or give deemed generation status

348. Financial performance of grid connection of MHPs is critically dependent on the percentage of surplus power that is evacuated to the grid. Therefore, it is crucial that either national grid availability is ensured or "deemed generation" status (take or pay[85]) is given to grid-connected MHPs by including this in the PPA. In the absence of such a provision in place in addition to NEA's unwillingness to finance the cost of a grid connection, the MHP community would end up bearing the entire risk of the investment. Moreover, the primary investment in the MHP would also be rendered risky due to encroachment of the national grid.

4.3.3. INSTITUTIONAL FINDINGS AND RECOMMENDATIONS

4.3.3.1. Effective coordination between NEA and AEPC to harmonize rural electrification programs

349. MHPs are supported by the AEPC, whereas the NEA manages the national grid (along with generation and distribution). As MHPs start interfacing with the grid, greater and more effective coordination between the two institutions is necessary. However, the two institutions are under different ministries (AEPC is under MoSTE and NEA is under MoEn) and coordination between them is infrequent and unproductive. Therefore, coordination between the NEA and AEPC requires an active role from the MoEn to facilitate information sharing and collaboration for planning and implementation. A unit/division within the NEA should be given the responsibility to oversee the rural electrification program through grid extension. The Small Hydro and Rural Electrification Division within the NEA, which was shut down in 2006, could be reestablished (or a similar unit established). The GoN has been subsidizing the CBRE program, which extends the national electricity grid to rural areas, through the NEA. Since the GoN provides subsidy support both

82 Weighted average of NPR 8.40/kWh (dry season) and NPR 4.80/kWh (wet season)
83 On a conservative estimate, typical installed cost/MW for SHP is NPR 170-200 million as opposed to NPR 400-450 million for MHP.
84 Since MHPs are proposed to be connected at 11 kV, when there is load-shedding on the national grid, they would not be able to evacuate power to the grid.

to CBRE and MHP programs, it is crucial that these two programs be harmonized so that the subsidies are utilized optimally and the MHP-grid interface issues are resolved in a planned way. Most importantly, the NEA and AEPC should collaborate to prepare a national rural electrification master plan.

4.3.3.2. GoN should protect MHP against grid encroachment

350. A local community invests in an MHP only if the GoN is unable to extend the national grid to provide electricity to that area. However, encroachment of the national grid into MHP distribution areas could render such investments stranded and impact not only the community but also BFIs. Therefore, when the grid eventually enters MHP distribution areas, it should be the GoN's obligation to safeguard the local community's investments and assets. Although the enabling law already exists in Sections 29 and 30 of the Electricity Act, 1992, it needs to be enforced and perhaps judicially reinforced if necessary. However, the Act promotes compensating the existing MHP and then abandoning the asset. Instead, it is recommended that the GoN should pursue a policy of purchase of power rather than abandonment of the MHP. If power is purchased from an MHP, it would transform the sector as well as redirect large sums of money into rural Nepal and help improve the local economy. Therefore, as long as it is financially viable for the community MHPs should be connected to the grid and their surplus power purchased as a general policy.

4.3.3.3. Grid-connected MHPs should be responsible to supply electricity to the community during load shedding in the national grid

351. If an MHP acts as an IPP after being connected to the grid and does not serve the local community at all, the rationale for AEPC subsidy (prior to grid connection) would not be justified. On a more operational level, such MHPs could be taken over through a lease or even outright purchase[86] by private investors who would make substantial profits (provided the PPA rate is financial attractive). Therefore, MHP as an IPP with continued responsibility to the local community (Option 2) should be the institutional model supported by the AEPC. The processes for nurturing the MHFG and helping it make the transition to a formal business organization will have to be piloted and tested by the AEPC and the RSC before scaling up grid-connected MHPs. Given that there is investment from the AEPC, community and local government in most MHPs, consensus would have to be developed on how the profits from the operation of MHPs should be shared. Moreover, the AEPC should build the capacity of RSCs and through them the community, to appreciate and understand incremental and total financial analysis as a preparatory step to grid connection. MHFGs should be upgraded to formal and legal entities before grid connection is enabled and a PPA is signed with the NEA.

4.4 WAY FORWARD

352. The power situation in Nepal is in a state of crisis. Although, there is no dearth of hydropower potential in the country, inadequate investments mainly on account of political instability and governance deficit has literally plunged the country into darkness. However, the GoN is committed to extending access to electricity to all parts of the country. The NEA and AEPC are the main drivers of this effort. There is a growing recognition of the importance of the AEPC in delivering access to electricity to remote rural areas of Nepal. This study underlines the importance of MHPs in doing so as the least-cost option to Nepal.

4.4.1. AEPC

353. Among the three pathways[87] analyzed in this study to further scale up access to electricity in the rural hills of Nepal, the AEPC should pursue the pathway of MHPs as standalone vigorously to reach out to as many off-grid communities as possible. This pathway has the greatest potential to transform lives in rural Nepal. Furthermore, the strategy, the institutions, the technology and the mechanism of delivery are well tested and robust. Therefore, AEPC should scale-up MHPs by reaching out to off-grid communities in the rural hills of Nepal.

354. The AEPC should also work in close coordination with the NEA and the relevant ministries at the GoN level to ensure that the recent decision of the NEA Board of Directors to allow MHPs to be grid connected and sell power to the NEA does not remain a working arrangement between the AEPC and the NEA, but is formulated into a policy of the GoN. Currently, the offered PPA rates are a good beginning, but they do not reflect real costs to the economy. Therefore, the AEPC should work with relevant institutions

[85] Alternatively, the NEA can guarantee a minimum payment equivalent to at least 50 percent off-take of power that the MHP is willing to supply to the grid, but is unable to do so due to grid non-availability.

[86] By paying the depreciated cost for the community portion of the capex.

(e.g. Electricity Tariff Fixation Commission) to create a policy basis for determining PPA tariffs for MHPs connected to the grid. Furthermore, unless there is guaranteed evacuation of all or at least the surplus power generated by the MHP, a policy on grid connectivity is ineffective. Therefore, the AEPC should work with the NEA on modifying the current PPA to include either a "deemed generation" status to MHPs or a guaranteed minimum payment on grid outages hindering evacuation of power from the MHP to the grid.

355. Given the reality of grid extension into rural Nepal, the AEPC should modify its current micro hydropower schemes to include the cost of metering and building an NEA standard distribution network in micro hydropower service areas so as to enable them to become grid ready. Furthermore, it should work in close coordination with donors and financial institutions to roll out a line of credit for grid connectivity of existing MHPs at low interest rates.

4.4.2. NMHDA AND THE MHP INDUSTRY

356. The NMHDA should work in close cooperation with the AEPC in scaling up the reach of MHPs to off-grid communities. More specifically, it should work with its members on the twin objectives of cost reduction and quality assurance. It should also seek the help and support of the AEPC, technical agencies and donors to help streamline the MHP manufacturing process. The AEPC should support the MHP industry in expanding business potential by helping them gain access to mini hydropower and ultra low-head technology by enabling technology transfer.

4.4.3. DONORS AND DEVELOPMENT AGENCIES

357. In the area of off-grid rural electrification, this study unequivocally shows that among the various RETs, where technically feasible, MHPs represent the least-cost option to the community as well as the economy as a whole. Furthermore, the study shows that economic benefits that flow from an MHP are robust and fully justify development investments in it in the form of capital subsidies. Therefore, scale-up and roll-out of MHPs in Nepal to enable off-grid communities gain access to electricity continues to offer an attractive avenue for donors.

358. Donors could support the AEPC to build capacity to steer a comprehensive policy in the area of grid connectivity of MHPs. Similarly, financing of grid connectivity offers a new area for donors to channelize funds through the banking sector rather than offering capital subsidies.

4.4.4. NEA

359. Grid connectivity of MHPs is a radically new step for the NEA. It will help the NEA gain well-organized and tariff-paying rural customers. In many cases where the distribution network is up to NEA standards, it would also not have to invest in creating an entirely new distribution network. The NEA would also gain access to power close to load centers and thereby save on transmission losses.

360. To enable the first grid-connected MHP under a PPA, the NEA should work with the AEPC to identify a suitable site. Using the experience gained during operationalization of the grid connection of that site, suitable guidelines for grid connection of MHPs could be drawn up by both the AEPC and NEA.

361. Overall, the study concludes that the AEPC should vigorously pursue scaling up MHPs as standalone installations. Simultaneously, it should work closely with the NEA to gain experience by operationalizing the grid connection of a few MHPs. Based on the experience gained it should also work on creating an enabling policy and procedure for grid connection of MHPs. As for mini-grids, the AEPC should support them on a case-by-case basis after carefully assessing the actual demand for off-peak power as well as financial and economic benefits.

[87] Scaling up MHPs as standalone, mini-grids and grid connected. See section 3.2

Annex 1:

Institutions involved in the micro hydropower sector of Nepal

This annexure briefly introduces various governmental and non-governmental agencies, which support the micro hydropower sector of Nepal.

ALTERNATIVE ENERGY PROMOTION CENTRE (AEPC)

The AEPC was established on November 3, 1996 as a semi-autonomous government agency governed by a Board of Directors. It is a line agency of the Ministry of Science, Technology and Environment (MoSTE) and works as a national focal institution for alternative and renewable energy promotion. AEPC's mandates are policy and planning, resource mobilization, technical support, monitoring and evaluation, standardization, quality assurance and coordination with stakeholders in the renewable energy sector.

The AEPC has succeeded in private sector development by involving over 400 private companies and more than 350 local enterprises in the renewable energy sector while creating 30,000 jobs at the local level and providing 1.5 million households with some form of renewable energy technology (RET). It has had positive impacts on rural education, health, and information and communications technology (ICT) sectors by providing electricity to 14 percent of the rural population. Various programs within the AEPC are briefly discussed herein.

REGIONAL CENTRE FOR EXCELLENCE IN MICRO HYDROPOWER (RCEMH)

The AEPC in partnership with USAID launched the RCEMH project in 2010 for the development and promotion of micro hydropower projects. RCEMH facilitates access to clean energy technologies throughout the South Asia region by stimulating new clean energy enterprises, promoting clean energy and improving economic opportunities to relieve South Asian countries, such as Nepal from rising energy costs. In addition, RCHMH organizes knowledge on completed micro hydropower projects and supplements it with regional best practices to make it available to community stakeholders, clean energy project developers and financial institutions across South Asia.

NATIONAL RURAL AND RENEWABLE ENERGY PROGRAMME (NRREP)

The AEPC started the NRREP on 16 July 2012 with support from the GoN and various international development partners such as the World Bank (WB), Asian Development Bank (ADB), United Nations Development Project (UNDP), United States Agency for International Development (USAID), Department for International Development (DFID), German Society for International Cooperation (GIZ), Danish International Development Agency (DANIDA), German Development Bank (KfW), Netherlands Development Organization (SNV), Norwegian Ministry of Foreign Affairs (NMoFA) and the European Union (EU).

The NRREP is mainly focused on improving the living standard of the rural population by increasing their productivity and employment rates, reducing their dependency on traditional energy, and integrating alternative energy with socioeconomic activities to attain sustainable development. The program will continue for five years with a total budget of US$184 million.

Breaking up foreign aid to support rural areas and the renewable energy sector has proven to be ineffective and has failed to deliver expected results in the past. Therefore, the NRREP organized itself as a single program modality such that all of AEPC's renewable energy programs supported by development partners are funded within the NRREP. This has helped to minimize inefficiencies, duplication, non-coordination and fragmentation of aid for rural areas and the renewable energy sector.

RENEWABLE ENERGY FOR RURAL LIVELIHOOD (RERL)

Between 1996 and March 2011, the UNDP-supported Rural Energy Development Programme (REDP) enabled more than 50,000 households to light their homes, cook their meals and power their enterprises from sources of clean energy. The REDP helped formulate policies and the institutional framework for decentralized development and management of rural energy supplies. By its end, the project had helped establish district energy and environment units (DEEUs)[88] in 72 district development committees (DDCs) for local energy development. It had also trained these communities to run and maintain their micro hydropower schemes.

Such success led to the REDP model being adopted by the Government in its landmark Rural Energy Policy (2006) and as the basis for its nationwide Micro-hydro Village Electrification Programme (MHVEP) funded by the World Bank.

RERL is an extension of the successful partnership between the GoN and UNDP in the renewable energy sector with an aim to consolidate the best practices from REDP and continue scaling up access to energy. This new program is being implemented by the AEPC and has begun work on reducing barriers that hinder wider use of renewable energy resources in rural Nepal. These barriers include policy and regulatory barriers, inadequate institutional capacity, the high cost of installing rural energy schemes, and limited technical expertise.

The RERL program will be a transition program before the full-fledged Global Environment Facility's (GEF) UNDP funded RERL program is finalized and brought into implementation in 2014 for the next five years. The program plans to link with the NRREP. The current RERL program aims to complete the joint commitments of the AEPC and the World Bank for achieving the target of 4.25 MW electricity generation through implementation of MHVEP. The program further supports the AEPC to consolidate the best experiences/practices of the REDP.

NEPAL ELECTRICITY AUTHORITY (NEA)

The NEA was established on August 16, 1985 under the Nepal Electricity Authority Act 1984, through the merger of the Department of Electricity of the Ministry of Water Resources, Nepal Electricity Corporation, and other related development boards. An individual organization was necessary to achieve efficiency and reliable service to remedy the inherent weakness associated with overlapping and duplication of works through fragmented electricity organizations.

The main objective of the NEA is to generate, transmit and distribute adequate, reliable and affordable power by planning, constructing, operating and maintaining all generation, transmission and distribution facilities in Nepal's interconnected or isolated power systems. NEA's other responsibilities are to recommend long- as well as short-term plans and policies in the power sector to the GoN, to determine the tariff structure for electricity consumption with prior approval of the GoN, and to manage training and study to produce skilled human resources in generation, transmission, distribution and other sectors.

NEA's Load Dispatch Centre (LDC) located in Kathmandu is at the heart of the national grid (also called the Integrated Nepal Power System (INPS)). Through the LDC, the NEA supervises and maintains the quality of electrical power supplied to the consumers, works towards maintaining balance between demand and supply, and tries to minimize power interruption. Supervision and monitoring is done through the computer-based Supervisory Control and Data Acquisition (SCADA) system that collects real time data from power stations and substations spread around the country.

DEPARTMENT OF ELECTRICITY DEVELOPMENT (DOED)

Electricity Development Center (EDC) was established on July 16, 1993 under the Ministry of Water Resources (MoWR). It was later renamed as the Department of Electricity Development (DoED) on February 7, 2000. Its main objective is to develop and promote the electricity sector to improve its financial effectiveness at the national level by attracting private sector investment. The DoED is responsible for assisting the Ministry in implementation of overall government policies related to the electricity sector. The major functions of the DoED include ensuring transparency of the regulatory framework, as well as promoting and facilitating private sector par-

[88] Now known as District Environment, Energy and Climate Change Sections (DEECCSs)

ticipation in the power sector by providing licenses and related services to all hydroelectricity projects.

WATER AND ENERGY COMMISSION SECRETARIAT (WECS)

The Water and Energy Commission (WEC) was established by the GoN in 1975 with the objective of developing water and energy resources in an integrated and accelerated manner. Consequently, a permanent secretariat of the WEC was established in 1981 and was given the name, Water and Energy Commission Secretariat (WECS). The primary responsibility of the WECS is to assist the GoN, as well as the different ministries related to water resources and other related agencies in formulating policies and planning projects in the water and energy resources sector.

NEPAL MICRO HYDROPOWER DEVELOPMENT ASSOCIATION (NMHDA)

NMHDA was established in 1992 as an umbrella organization for private companies working in the micro hydropower sector in Nepal. Its major objective is to spread knowledge and expertise in surveying, designing, and manufacturing of micro hydropower plants (MHPs) and necessary equipment, as well as installing, commissioning, and after-sales services of MHPs.

It aims to influence the hydropower policy of Nepal for promotion of micro hydropower technology, provide technical support on MHPs to its members, and conduct activities for promotion, training and research in this sector. NMHDA has been working as a liaison between the GoN, various donor agencies, and private companies for the development of the micro hydropower sector.

THE WORLD BANK (WB)

The WB approved a Power Development Project in 2003 consisting of a US$75.6 million International Development Association (IDA) credit to assist the GoN in meeting its power sector objectives. A complementary Carbon Offset Project to provide additional financial support to AEPC's Nepal Village Micro Hydro Program (NVMHP) was established.

The Carbon Offset Project aims to develop a viable off-grid micro hydropower market for villages, which will not be served by the national grid for at least five years. It offers support to both the demand and supply sides by providing information and social mobilization support, technical training, investment subsidy to communities, market information, and business development support services to micro-hydropower construction and supply companies. It also brings together rural electrification activities supported through the micro hydropower component of the World Bank Power Development Project. It is thus helping improve access to electricity services in rural areas.

AGRICULTURAL DEVELOPMENT BANK LIMITED (ADBL)

The ADBL was established in 1968 with the objective of providing institutional credit to the rural population of Nepal. It first provided credit for turbine mills. When these mills proved successful, it later started providing credit for electrification of these mills. Eventually, the ADBL started financing isolated MHPs.

ADBL was the pioneer institution that made investments in the micro hydropower sector of Nepal. It played an important role in promoting and creating access to alternative energy for the rural population. In the beginning, ADBL provided credit support and mobilized GoN's subsidy. However, after the transfer of the subsidy delivery duties to the AEPC, it has been performing credit delivery and management roles.

PRACTICAL ACTION

Practical Action's Energy program in Nepal plans to benefit rural populations by increasing access to green energy in lighting and cooking. The program focuses on providing an enabling environment as well as developing and testing new innovative ideas to engage and increase the role of the private sector in providing access to modern energy resources, and financing. The program hopes to demonstrate a decentralized energy system with particular focus on achieving minimum energy standards and total energy access to achieve universal access to energy by 2030.

Practical Action is involved in planning and implementation of advanced climate resilient energy access; increasing private sector participation in the energy access market; mobilizing demand for energy services in marginalized communities; introducing minimum energy standards for energy access; and ensuring productive end-use of energy for sustainable livelihood of poor households.

In the 1990s, Practical Action was known as Intermediate Technology Development Group (ITDG). The then ITDG was actively involved in promoting MHP technology including financing site installations of pilot projects.

Annex 2

Details on plants visited and plant performance

This annex provides a brief description of site visits undertaken in the month of May, 2014 for the World Bank Technical Assistance titled *"Nepal: Scaling up Electricity Access through Mini and Micro Hydropower Applications: A strategic stock-taking and developing a future roadmap (TA #P144683)"*. Sites visits included MHPs, community managed electrical distribution systems, RSCs and a number of MHP manufacturers and installers in Butwal.

Tables A2.1 and A2.2 list the various MHP sites, CBRE sites and other service providers in the sector that were visited. In addition, consultations were also undertaken with Nepal Micro Hydropower Development Association, and other consulting firms such as MEH, Sustainable Energy and Technology Management.

TABLE A2.1 | List of MHP sites visited

S. No.	Date of Visit	Name of MHP	Location
1	11 May, 2014	Gottikhel MHP	Gottikhel, Lalitpur
2	12 May, 2014	Midim Kholan MHP	Ishaneshwor, Lamjung
3	13 May, 2014	Bhujung MHP	Bhujung, Lamjung
4	17 May, 2014	Ghandruk I MHP	Ghandruk, Kaski
5	18 May, 2014	Ghandruk II MHP	Ghandruk, Kaski
6	18 May, 2014	Malekhu I MHP	Mahadevsthan, Dhading
7	18 May, 2014	Malekhu II MHP	Mahadevsthan, Dhading
8	19 May, 2014	Daram Khola I MHP	Wamitaxar, Gulmi
9	19 May, 2014	Daram Khola II MHP	Wamitaxar, Gulmi
10	20 May, 2014	Giringdi Kholan MHP	Kharbang, Baglung
11	25 May, 2014	Yafre MHP	Taplejung

TABLE A2.2 | List of stakeholders visited

S. No.	Date of Visit	Name of Stakeholder	Location
1	8 May, 2014	South Lalitpur Rural Electric Cooperative	Lalitpur
2	14 May, 2014	Lamjung Electricity Users Association	Beshi Sahar, Lamjung
3	27 May, 2014	North Engineering Company Pvt. Ltd	Butwal, Rupandehi
4	27 May, 2014	Nepal Hydro & Electric Limited	Butwal, Rupandehi
5	27 May, 2014	Oshin Power Service Pvt. Ltd	Butwal, Rupandehi

KEY FEATURES OF SITES VISITED

Key features of the sites that were visited during May 2014 are summarized herein.

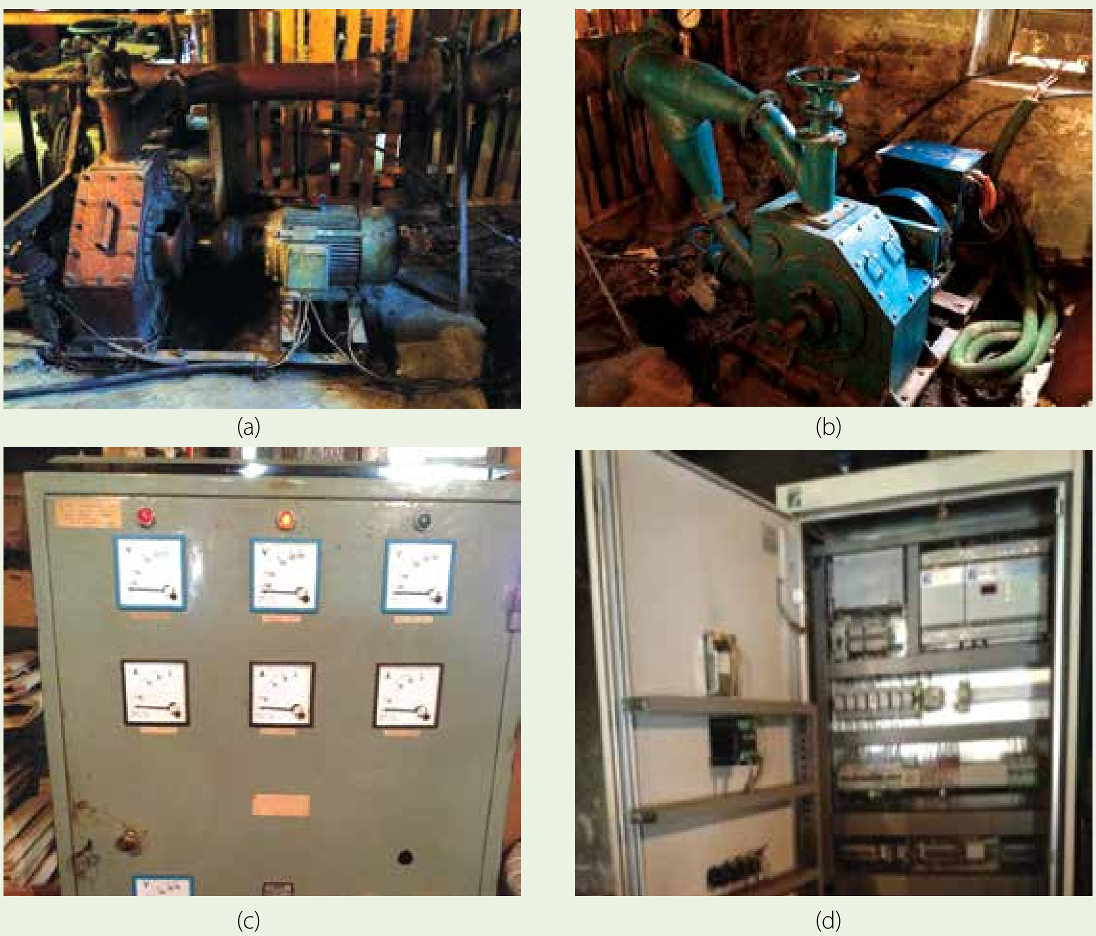
I. GOTTIKHEL MHP

The Gottikhel MHP located in South Lalitpur district runs two different systems: an older 16 kW isolated system and a newer 24 kW grid connected system. The old 16 kW turbine-generator unit supplies electricity to consumers in an isolated mode. The new 24 kW turbine-generator unit was installed as a pilot project for grid connection with support from the AEPC and GiZ. This is the first isolated MHP in Nepal to be grid connected.

The 24 kW system was successfully connected to NEA's grid for four months and then disconnected because the MHP owner (this is an entrepreneur run MHP) did not receive any payment for the electricity supplied to the NEA grid. The NEA grid system in this area is managed by South Lalitpur Rural Electric Cooperative (SLREC). However, the Gottikhel MHP and SLREC (or NEA) had not worked out any FIT agreement, i.e. the rate at which the distribution system was to buy the electricity supplied by the micro hydropower sector as well as other conditions, such as maintenance responsibility of the distribution lines, were not decided upon.

Keshab Ghimire, the head and owner of Mahankal Bahuuddeshiya Utpadan Samuh Pvt. Ltd in Got-

Figure A2.1 (a) 18 kW system (b) 24 kW system (c) Control panel for 18 kW system (d) Control and synchronizing panel for 24 kW system of the Gottikhel MHP



tikhel mentioned that the 20 kW MHP was set up in 1995 with support from SNV (NPR 385,000), ADBL (NPR 900,000 @ 10 percent rate of interest) and Kathmandu Metal Industries (NPR 1 million). The loan from Kathmandu Metal Industries was interest free and was repaid by Ghimire over a period of 12 years.

Drawing from his earlier experience of running a 6 kW plant, Ghimire opted for a HDPE-based head-race even though it was costlier than a simple masonry structure. This, he claims has helped him run the plant 24-hours a day all seven days of the week for the past 19 years even though several landslides occurred in the area during this period.

Until the grid was extended into the distribution area of this MHP, it supplied power to 152 households @100 W/household for NPR 100/month. In addition, it also powered a rice huller, oil press, welding unit, masala grinder, maize huller and a sawmill, all operated by Ghimire's company at the MHP site.

The total monthly revenue from sale of electricity and services rendered by the end-uses listed above amounted to approximately NPR 85,000. Of this only about NPR 16,000 came from households, indicating the importance of end-uses to this company's top line and bottom line. Since the arrival of the grid, revenue plummeted down to NPR 30,000–40,000/month, primarily on account of end-use applications. Ghimire continues to supply electricity to 80 households, and claims that he no longer collects payments from them.

With the advent of the grid two new end-uses have come up such as a Xerox center and a computer center. Both these need regular electricity supply which the grid is unable to ensure. Therefore, these units have also subscribed to Ghimire's power supply for which they pay NPR 500/month (as per Ghimire's statement).

Upon the arrival of the grid, consumers from the five wards that Ghimire supplied power to and some from other wards travelled to his plant site to have their grains processed. Once the grid coverage area expanded over large parts of Ghimire's distribution area, several agro-processing units got established, which have cut into his end-use business. The end-user is greatly benefited by this development as households get served closer to their doorstep.

II. MIDIM KHOLAN MHP

The 100 kW Midim Kholan MHP located in Ishaneshwor, Lamjung district has signed a PPA with the NEA. The PPA rate (NPR 3.27/unit for the wet season and NPR 5.73/unit for the dry months) was set by the NEA on the basis of the total cost of the MHP excluding the subsidy amount provided by the AEPC. However, the actual power generated by the MHP during test runs has been only 83 kW. Due to the undersized head-race canal and partially completed tail-race canal it has not been possible to divert the entire design discharge; and thus the reason for the inability to generate 100 kW of power output. This power plant is near completion and work on grid synchronization was ongoing during the site visit period.

The plant is run by Shree Deurali Bahuuddeshiya Sahakari Sanstha — a cooperative that was started about 14 years ago with GTZ support for promoting dairying in the area. Currently, it has 1,500 members who are all expecting to receive dividends from profits accrued from sale of excess power to the NEA. Interestingly, the Paschim Lamjung Community Electricity Users Association distributes NEA power in the local area. However, at the time of our visit there had been no power supply from the grid for the past few months, due to technical reasons.

Ironically, the local MHP (which is owned by the Cooperative) was also not in operation because of pending electrical works and some significant civil structure modifications. Thus, the people of this area were receiving power from neither the MHP nor the grid.

Om Raj Ghimire, the president of the Cooperative said that the Cooperative took over an existing 40 kW system by repaying the previous owner's loans. The Cooperative, making a clear departure from its existing activities, decided to get into electricity generation and distribution because it felt that it could serve the community better whilst also adding significantly to its bottom line. The old 40 kW MHP was demolished and a new 80 kW plant was built which was further modified to produce 100 kW by increasing the head. However, Ghimire claims that the contractor did not take into account the water needed for irrigation in the area and thus, the plant was not able to run at full capacity for want of adequate quantity of water.

Ghimire felt that the quality of service and advice provided by the contractor and the RSC in the area was not satisfactory, and that they were overcharged for the electro-mechanical portion of the plant. On hindsight, he felt that if the Cooperative itself had executed the plant's construction, they could have done it for half the cost.

As for the PPA with the NEA, Ghimire said that it took a lot of effort and money to materialize and that he had to camp in Kathmandu for nearly a month to persuade the NEA to offer a PPA at a reasonable rate.

As per the PPA and the projection given to them by the installer and the AEPC, a revenue of NPR 3.3 million/year is expected from the sale of 800,000 units/year to the grid (this means operating at 91 percent plant load factor, a tall order considering plant downtime and grid downtime) and a profit of NPR 2.2 million/year. However, it is three years since work began on the 100 kW MHP and it is yet to be completed and connected to the grid.

Figure A2.2 (a) Turbine and generator set (b) Cooperative office (c) Power transformer for grid connection (d) Consultants meeting with the Cooperative President of Midim Kholan MHP

(a) (b) (c) (d)

III. BHUJUNG MHP

The Bhujung MHP located in Bhujung, Lamjung district consists of two cascaded MHPs: an upstream MHP of 80 kW and a downstream MHP of 20 kW. The 80 kW MHP is running well; however, it is only generating 64 kW (this power plant has never generated the full 80 kW rated capacity). The 20 kW MHP was not operational during the site visit. The community plans to synchronize these two MHPs and work on the synchronization is ongoing. The MHPs are under the supervision of the MHP Management Sub-committee, which is a part of the Conservation Area Management Committee. Technical, financial and management support is provided by the Annapurna Conservation Area Project (ACAP).

The tariff has now been reduced from NPR 100 per month per 100 Watts to NPR 65 per month per 100 Watts. This is because once all loans were paid back the community decided to lower the tariff.

Bhujung MHP is serving various end-uses, such as agro-processing units, sawmills and ropeway lines (that are used to transport harvest from the lower fields as well as to supply construction materials from the riverbank to the village). Apart from household lighting, the community has also started using electric appliances, such as rice cookers and televisions.

This MHP supplies power to Bhujung, Kamigaon, and an adjoining village situated across the valley. Kamigaon is a Dalit-dominated village, while Bhujung is a Gurung village and is part of the Annapurna conservation area and has been preserved to showcase Gurung culture and way of life. Access is by a winding steep climb from Besishahar that takes about three hours on a 4-wheeler. The road ends abruptly from where one descends into Bhujung by way of a set of steep stone-hewn steps. All nine wards of the VDC are set into the steep hillside overlooking a deep but narrow valley that houses the power plant as well all village farms.

Figure A2.3 (a) Operational 80 kW system (b) Not operational 20 kW system (c) Sawmill (d) Agro-processing mill served by the Bhujung MHP

(a) (b) (c) (d)

There are three agro-processing units and three sawmills in the village that use power from the MHP. Each plant uses a 7.5 kW motor and pays a tariff of NPR 8/kWh. Pitraman Gurung, the owner of a sawmill, said that he ran his plant for only a few months in a year depending on local demand. Given the poor access to the village, he does not have any clientele to cater to beyond Bhujung. He mentioned that he paid about NPR 8,000/year that amounts to 1000 kWh/year, which is equivalent to running his 7.5 kW motor for about 134 hours in a year.

Ram Prasad Gurung who runs a rice huller said that he ran his huller for about six months in a year when there was grain to be hulled in the village. Given the high starting current needed for running the huller, he works on alternate days so that other hullers in the area can also operate without overloading the plant.

All productive end-uses are allowed to function only during 08:00-17:00 hours. Domestic load, which is almost 56 kW of the 64 kW produced, is mainly for lighting and television. Although some of the households use rice cookers, in the absence of adequate voltage, it is not convenient. The ACAP had distributed rice cookers when the MHP was set up, to encourage use of electricity as well conserve forests by reducing the use of firewood for cooking. However, with increase in use of lighting and TV (almost 80 percent of households have it) and a flat tariff structure (NPR 65/100W/month), domestic usage (365 households) has highly increased.

IV. GHANDRUK I MHP

Ghandruk I MHP, a 50 kW plant located in Kaski district, is the first phase and upstream plant of the cascaded Ghandruk MHP system. It is also being run under the supervision and support of ACAP. The intake of the site is situated far away. Due to landslides and floating vegetation (leaves and twigs), regular maintenance and cleaning of the intake structure is necessary. For a weekly cleaning of the intake, personnel from Micro Hydropower Management Sub-Committee need to travel for almost half a day.

Figure A2.4 (a) Turbine and generator set (b) Signboard of the MHP (c) Manager and operator of the Ghandruk I MHP in front of the powerhouse

(a)

(c)

(b)

As this was one of the first MHPs installed (1992) in the Annapurna region, the community received substantial support from various organizations and donor agencies such as the ACAP, Canadian International Development Association (CIDA), Intermediate Technology Development Group (ITDG – now renamed as Practical Actions), British Embassy, and World Wildlife Fund (WWF–US).

As Ghandruk is along a popular trekking route in the Annapurna region, it receives a high influx of tourists most of the year. There are over 30 hotels that cater to trekkers and tourists. All these hotels are supplied with electricity generated from Ghandruk I (13 hotels) and Ghandruk II (18 hotels) MHPs.

Apart from supplying electricity to the hotels and households, Ghandruk I MHP also provides electricity to a Nepal Telecom Corporation (NTC) tower. As this power plant was not able to meet the peak load demand of the area (and increase end uses), the community decided to build a cascade MHP downstream of Ghandruk I MHP.

V. GHANDRUK II/ BHIRGYU MHP

Ghandruk II MHP is the second phase and the downstream plant of the cascaded Ghandruk MHP system. This power plant (commissioned in 2012) is also being run under ACAP's supervision and support. This MHP utilizes tail-water from the upstream Ghandruk I MHP.

Figure A2.5 (a) Powerhouse and the penstock alignment of Ghandruk II (b) Turbine and generator set (c) Interview with consumer (d) Rice cooker in use

End-uses of this MHP comprise a paper making (Nepali paper known as Lokta) enterprise, a water purification system, two bakeries, 18 hotels and a monastery. Like all ACAP-supported MHPs, an MHP Management Sub-committee, which is part of the Conservation Area Management Committee formed from the local community, also manages these two.

Sundevi Gurung of Ghandruk is the Chairperson of the Ward 7 Women's Group. Her group puts up cultural shows to raise funds for development works in the village. She started out with a 100 W connection 15 years ago when Ghandruk I began operations. She had four bulbs of 25 W each totaling 100 W for which she paid NPR 100/month, which was reduced to NPR 65/month. When Ghandruk II was commissioned she was offered another 100 W connection, which she subscribed to immediately. In addition, she bought the rights to 100 W of connection for NPR 10,000 from her neighbor who did not want the additional allotment from Ghandruk II. Finally, she managed to convince other neighbors to let her use another 200 W from their quota of an additional 100 W each, making a total of 500 W of sanctioned load to her household.

All these deals for more power were to run a rice cooker (300 W), water heater (350 W), television, six CFLs and one bulb. During our visit in the evening, the rice cooker was being used. Sundevi mentioned that she used her rice cooker twice a day for about 30 minutes each. The water heater and the television are kept on throughout the waking hours. She reckons that the rice cooker does not save much fuel wood but provides great convenience in cooking.

Similarly, Kisam Gurung, owner Gurung Cottage started with a 100 W connection for his hotel that has increased to 1200 W acquired through a combination of subscribing to the additional allotment of 100 W to each subscriber once Ghandruk II came on stream and from purchases of rights to use the additional 100 W from other households that did not find the additional 100 W useful since they could not use it for anything other than lighting. Currently, he is paying a flat tariff of NPR 2/W/month.

Both Sundevi and Kisam are happy with the service but want more power; Sundevi wants to set up a hotel while Kisam wants to offer more services for which he needs more power. He is ready to subscribe to another 800-1000 W if it would become available. He mentioned that a survey carried out in Ghandruk revealed that there is an unmet demand for 147 kW even after Ghandruk II has been commissioned.

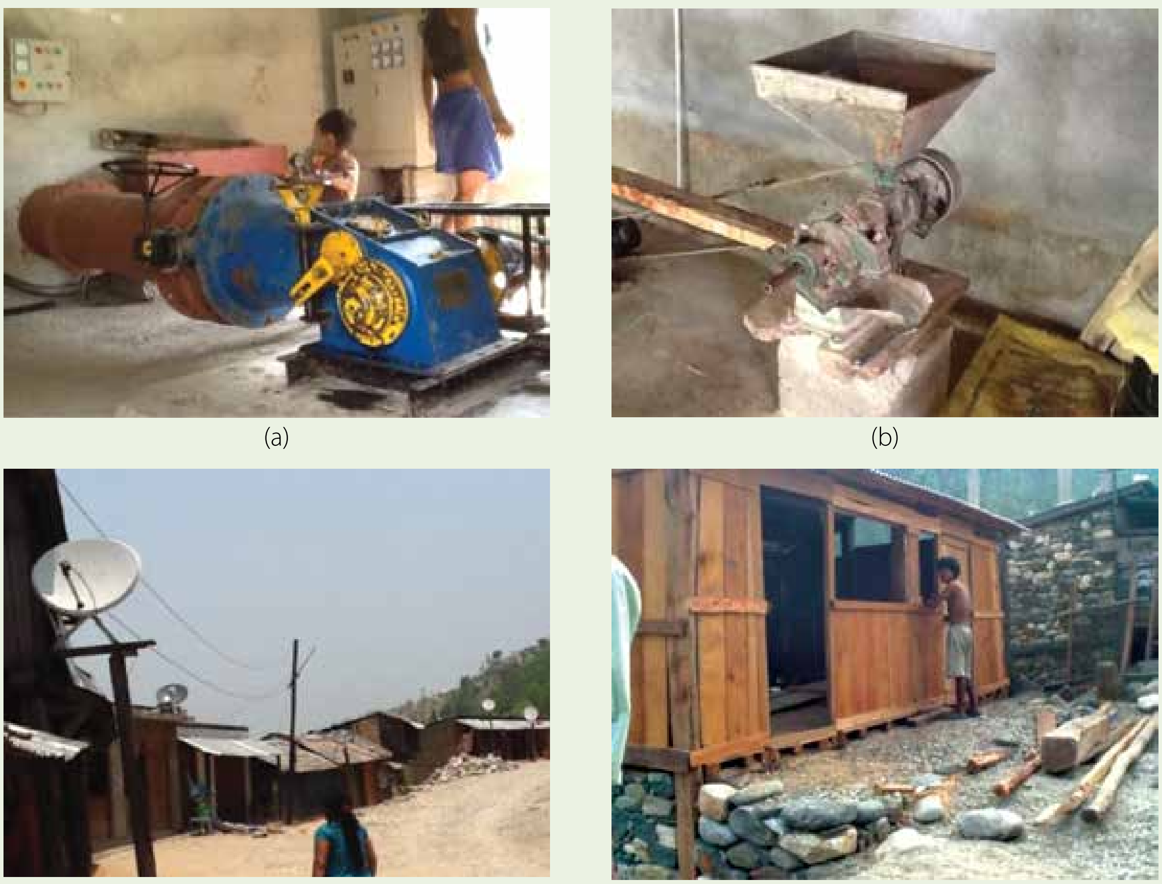
Mankaji Sunar, a Dalit, started with a 100 W of connection 15 years ago and has since moved up to 400 W and is paying a fee of NPR 600/month. He and his family contributed about 30 days of labor (at NPR 400/man day) during the construction of Ghandruk II. Similarly, Aitha Kumari Parihar and Sunsari Parihar (both Dalits) have subscribed to 200 W but find that they cannot use a rice cooker due to poor voltage. Indeed, it appears that for many households using a rice cooker is aspirational.

VI. MALEKHU I MHP

Malekhu I MHP is a 26 kW capacity plant located in Mahadevsthan VDC, Dhading district. The distribution area of this MHP is about one hour's drive on the gravel road from Malekhu town along the East–West highway. The NEA grid has arrived close to the MHP distribution area. Mahadevsthan is a developing town and the power plant is currently unable to meet the peak hour demand.

Apart from household lighting, other end-uses from this MHP comprise four small poultry farms, one sawmill and one rice mill. Furthermore, many households within the distribution system of this MHP use televisions.

Figure A2.6 **(a) Turbine and generator set (b) Agro-processing mill (c) Satellite dish antenna (d) Woodworking shop served by Malekhu I MHP**



(a) (b) (c) (d)

VII. MALEKHU II MHP

Malekhu II MHP is a 18 kW plant located in Mahadevsthan VDC, Dhading district. The powerhouse of this MHP is about 4 km upstream from the powerhouse of Malekhu I MHP. The headrace canal of this power plant is also extensively used for irrigation. During the irrigation season, the power plant is shut down during the day as also there seems to be minimal demand for electricity from 10:00 am to 4:00 pm. This MHP also has excess power than the existing demand. Thus, the AEPC is considering establishing a mini-grid connecting Malekhu I and II MHPs. The mini-grid system will be at 400 V (which is at a lower level compared to the 11 kV Baglung mini-grid).

Apart from household lighting, other end-uses from this MHP are: a sawmill, a rice sheller (huller), a grinder (to make incense "Sinkedhup"), and a lift irrigation system (to supply water to uphill terraces (from the head-race canal)).

Figure A2.7 (a) Turbine and generator set (b) Control panel (c) Irrigation pumping done at Malekhu II MHP

(a)

(b)

(c)

VIII. DARAM KHOLA I MHP

The Daram Khola I MHP is the upstream MHP of the cascaded Daram Kholan MHP system. It is located in Wamitaxar, Gulmi district and is run by the Paropkari Co-operative. Although designed for 116 kW, this MHP is generating 135 kW. Major problems include maintaining the head-race canal and the short lifespan of wooden distribution poles.

The site is running well and commercial customers are paying NPR 1,500 for the first 190 units. Productive end-uses from this MHP include 13 agro-processing units, two sawmills, 10 poultry farms, an NTC tower, an Ncell tower and a computer center. The MHP is planning to add a 100 kW aggregate crusher during the off-peak hours.

This MHP is run by Paropkari Sahakari Sanstha, which is headed by Dharmendra Kr. Malla. This plant caters mainly to rural areas surrounding the Wamitaxar bazaar. The cooperative has a total membership of 1,685, each of whom has contributed NPR 5,000 as share capital. The cooperative started its activities about 20 years ago focusing mainly on savings and credit. It ventured into the business of electricity generation and distribution based on the experience of its Executive Committee members who were already running Daram Khola II as private entrepreneurs. The cooperative is planning to set up a 1 MW mini hydropower plant on a PPP mode.

This 135 kW MHP has surplus power even during peak hours and supplies power across the stream to Kharbang in Baglung district.

Figure A2.8 (a) Powerhouse (b) Two coupled turbines and the generator set of the Daram Khola I MHP

(a)

(b)

IX. DARAM KHOLA II MHP

Daram Khola II MHP is the downstream MHP of the cascaded Daram Kholan MHP system. It is located in Wamitaxar, Gulmi district and is run by a private entrepreneur. Although designed for 70 kW, the MHP is generating 85 kW. A major problem is the short lifespan of wooden distribution poles.

The site is running well and commercial customers are paying NPR 1,500 for the first 190 units. Productive end-uses include agro-processing units, three sawmills, three welding shops, a noodles factory, and a computer center.

Two entrepreneurs (Dharmendra Kr. Malla and Agnidhar Ariyal) from Wamitaxar who invested initially about eight years ago, sold out 50 percent of their stake to a local school which made the investment to earn returns. The entrepreneurs started out with a 10 kW watermill in the area before attempting the 85 kW Daram Khola II plant.

The plant caters to 900 customers now, but when it began operations it was serving a mere 400. Today, the plant is overloaded, especially during evenings when the load of all households comes online. The plant serves Wamitaxar bazaar, which means a number of shops and establishments.

Figure A2.9 Figure A2.9 (a) Powerhouse with penstock alignment (b) Coupled turbines and the generator set of the Daram Khola II MHP (c) Agro-processing unit (d) Karki Grill Udyog

(a) (b) (c) (d)

Srijana Cyber and Stationery is a shop run by Yamuna Ghimire (also an executive committee member of the Paropkari Cooperative) and receives power from Daram Khola II. Yamuna started the cyber café in 2006 and offers printing, scanning, photocopying, email, e-ticketing services. But the main business is offering Skype calls at NPR 50/hour. Wamitaxar and its surrounding areas have a large population who work outside Nepal and Skype calls are a cheap way for their families to keep in touch. Yamuna started with a 2A connection, but soon shifted to a 5A connection. Her monthly bill is around NPR 500 (of this NPR 300 is for the first 40 kWh and remaining NPR 200 is for 25 units @ NPR 8/unit). Thus, on an average she uses about 65 kWh/month. However, this includes her household use as well. She uses two bulbs (60 W), 14 CFLs (3 x 15 W and 11 x 7 W), a television, a rice cooker (not able to use it due to very low voltage), a pressing iron, a table fan and a ceiling fan. This is in addition to three desktops, a scanner, a printer and a photocopying machine.

Narayan Prasad Shakya runs a flour mill-cum-rice huller using a 7.5 kW electric motor. Earlier he was running a diesel (8 hp = 5.96 kW) engine for the same purpose. Typically, the diesel engine consumed 1 liter of diesel/hour and ground 100 paathis (1 paathi = 4 kg) of grain in an hour. He charged NPR 5/paathi. Using an electric motor (7.5 kW) he is able to grind 240 paathis (960 kg) in an hour consuming 7.5 kWh of energy. He charges NPR 2.5/paathi now. Thus, the final customer has gained substantially in terms of reduced charges for getting their grain ground. Narayan keeps his outlet open from 07:00-

10:00 hours and 15:00-18:00 hours every day for 20 days in a month for all 12 months of the year. On an average his monthly bill is NPR 2,200, which translates into 280 kWh/month (NPR 1,500 for 190 kWh and rest at NPR 8/kWh). Narayan also runs a photo studio, which has a separate electrical connection.

Basant Bahadur Karki runs a grill and welding shop under the name Karki Grill Udyog. He used to work in India, but decided to return to his village 15 years ago when he heard that a road was being laid through Wamitaxar. The road opened new avenues of income for the area. Karki found that a number of vehicles were moving through Wamitaxar and started offering puncture repair and air-filling services which were both done manually. When power supply began in the area with Daram Khola II he decided to expand his services to include welding and slowly graduated to grill making, vehicle washing, etc. He says that his income has doubled due to availability of electricity. Today, he employs seven to eight people. His monthly bill is around NPR 2,500. However, this includes his domestic use as well, which comprises a rice cooker. Since the voltage is very low during the day, he carries out all welding work at night long after the households have gone to sleep.

Raju Parihar is a Dalit who runs Ranu Tailoring in Wamitaxar. He started with a 2A connection but soon shifted to a 5A connection since he could not use the pressing iron with a 2A connection. Even now he cannot use the iron during 18:00-21:00 hours, but manages by scheduling it for other times of the day when the voltage is better. He also uses electricity to run his tailoring machines and claims that he would not have been able to handle the volume of business but for electricity.

Figure A2.10 (a) Digital photo studio (b) Jeweler working at night (c) Popular brand of rice cooker (d) Pradhan's electric shop

(a) (b) (c) (d)

X. GIRINGDI KHOLAN MHP

Giringdi Kholan MHP is located in Kharbang, Baglung district. This MHP, initially operated by an entrepreneur, is owned and operated by Giringdi Khola Laghu Jal Vidyut Sahakari Sanstha — a cooperative that was set up exclusively for the purpose. Headed by Mitra Bahadur Pun, a former VDC President, one striking feature of its executive committee that manages this MHP is their evident pride in the plant and their confidence in running it.

Designed for 75 kW it now generates 85 kW but it gets overloaded during peak hours (from 6:00 pm to 9:00 pm); daily load shedding also occurs in parts of the distribution system.

Apart from lighting uses, the productive end-uses of the MHP includes four fresh houses, five schools, one X-ray machine, three welding shops, four sawmills, seven agro-processing mills, four digital photo studios, two cable TV providers, 15 poultry farms, one noodle factory, and one radio station.

The MHP has 868 connections of which 23 are industrial (each with 6A connections). The rest are largely households. Nearly 75 percent of connections are up to 1A. The total monthly revenue is NPR 110,000 of which NPR 35,000 is from the 23 industrial customers, thus underlining the dominance of household loads. All customers are metered and meters are purchased by the end-users themselves.

The MHP has enabled several enterprises to set up shop in the Kharbang bazaar area. The Baglung Kalika Engineering Workshop is owned and run by Chandra Vishwakarma, who returned from Malaysia where he was working at a plant that produced designer garden lights and fixtures. He has put that knowledge and experience here in producing grills and other structural items. His monthly electricity bill is NPR 2,000–2,500 (the first 100 kWh is charged at NPR 800 and the rest is at NPR 8/kWh) that amounts to about 250–300 kWh/month. He is satisfied with the MHP power supply, but is affected when the MHP is shut down for a number of days for repairs. He is interested in taking a NEA grid connection, but plans to keep this connection as well since the NEA grid has a lot of load shedding. He has paid NPR 1,000 as connection charges and NPR 5,000 for getting a meter, which had to be replaced at his cost if it breaks down.

Drona Van owns and operates Kharbang Chowmein Udyog. Before returning to his village, he had

Figure A2.11 **(a) Powerhouse (b) Turbine and generator set (c) Control panel and the MHP system of Giringdi Kholan MHP**

(a) (b) (c)

Figure A2.12 **(a) Drona van making noodles (chowmein) (b) Students using mini-laptops (c) FM radio station**

(a) (b) (c)

worked in India and Dubai. His last visit to Dubai was through a broker on a false work permit that caused him to lose NPR 150,000. This is when he decided to set up a business in his own village. With support from the REDP and encouragement from his parents, he hit upon the idea of producing chowmein, which he found was being consumed by many restaurants and households in Kharbang bazaar. He uses two motors of 2.25 kW and 1.5 kW each for making the dough and for producing chowmein from dough. His monthly bill is NPR 1,300–1,800, which amounts to 160–230 kWh/month. Although the mixer and the chowmein maker can produce 400 kg of chowmein in a day (eight hours), he makes only 100 kg since the chowmein has to be cooked before it is either sold fresh or after drying (mainly sun drying). On an average he makes a net profit of NPR 7/kg of chowmein sold.

Shree Tribhuvan Uccha Madhyamik Vidyalay, Kharbang is a government-run school. It has a full-fledged computer lab that has access to the Internet and other teaching aids in the form of CDs. It has 50 mini laptops that have preloaded textbooks for students of classes 2–7 and covers subjects such as mathematics, science, English and Nepali. The school also runs basic computer literacy classes for its students for which it charges NPR 1,000/student/course. Teachers find the computer lab very useful since it gives them access to a large pool of subject matter as well as learning and teaching materials.

Radio Saarathi is a community FM radio that is managed by Bishnu Bhusal. It was set up with assistance from the REDP and has a 100 W transmitter in addition to a mixer, computer, and other items. It runs on revenues from local and government advertisements. The radio station consumes 250–300 kWh/month and broadcasts from 05:00 to 23:00 every day.

XI. YAFRE MHP

Yafre MHP is located in Taplejung district and run by the Micro Hydropower Functional Group (MHFG). It was designed for 95 kW output but generates 112 kW and its peak load is only 75 kW; therefore, it has excess power than its peak demand. As a nearby MHP serving the Phungling bazaar is facing heavy electricity shortage, the local population in the bazaar area is currently using a diesel generator set synchronized with a NEA mini hydropower to serve the demand during peak hours. There is a potential to connect and synchronize Yafre MHP instead with the NEA mini hydropower to power Phungling bazaar. The AEPC has initiated a study on establishing a mini-grid system to serve Phungling bazaar and its outskirts.

The diesel generator had broken down during the site visit. When it was operational, the electricity sold from diesel generation was making a loss, due to increase in price of diesel. Apart from lighting uses, the productive end-uses included two agro-processing mills and three poultry farms.

The Yafre MHP is a year old and provides power to 870 households. It was built at a cost of NPR 40 million of which the community cash contribution was NPR 10.4 million and community labor contribution was about NPR 3.5 million which also included labor for making a 3 km road to facilitate transportation of MHP-related equipment. The MHFG was formed in 2008 and the contract for building the plant was given in 2011. The plant was commissioned in 2013 as the community took nearly three years to mobilize their contribution. The plant is providing power to two agro-processing units, and three poultry units. A papermaking factory and a computer center are being set up now.

The agro-processing units were earlier run by diesel engines and charged NPR 3/kg for hulling and NPR 4/kg for grinding. Now they charge NPR 2/kg for hulling and NPR 3/kg for grinding. On an average, each unit pays NPR 5,000/month towards electricity charges.

XII. LAMJUNG ELECTRICITY USERS ASSOCIATION, BESISHAHAR, LAMJUNG DISTRICT

The LEUA began operations in 1997 with full funding support from NORDIC. Currently, it covers 34 VDCs in Lamjung and three in Tanahun districts covering 24,000 customers. The total connected load is 8 MVA. There are 161 distribution transformers.

Figure A2.13 **(a) Turbine and generator set (b) Control panel of Yafre MHP**

(a) (b)

There is no load shedding in Lamjung district due to the presence of two to three large hydropower stations built on Marsyagdi river that supply power to the national grid. LEUA purchases 10 million kWh/year from the NEA. The main problem they are facing is low load density in rural areas and high cost of replacing electric poles, especially the older ones that are usually wooden.

Harish Chandra Acharya, the Overseer says that they are barely able to meet their operations and maintenance costs. But for the presence of a large bazaar in the distribution area in the form of Besishahar, Bhotevadar, Khimti and Sundar bazaars, the load would be largely domestic and at a low density. A typical rural portion of their distribution area would have a 25 kVA transformer for about 65 households. Assuming a loading of 70 percent of the capacity, this translates to about 220 W/household that is at least twice the available capacity for use by households (110–130 W) being served through MHPs.

XIII. MEETING WITH RSCS

The team met with RSCs at Baglung (DCRDC) and Illam (NCDC) who have been working for nearly 10 years with the main task to promote all AEPC technologies, such as SPV, biogas, improved cookstoves and micro hydropower. For promoting micro hydropower they have a set of dedicated staff that include engineers and field coordinators. The DCRDC works in 10 districts in central and western parts of Nepal, while the NCDC works in three districts in eastern Nepal.

The key issues highlighted by both RSCs are listed below:

- Since AEPC is centralized, time taken to process applications for carrying out pre-feasibility studies, subsidy release, etc. takes a long time.
- Quality control at field level, especially for civil works is not possible because the RSC has limited staff, a vast area to cover and a huge scope of work.
- Usually, civil works supervision is left to the installer while the local community executes it. Often, the quality of work is below acceptable standards.
- RSCs are not equipped with appropriate instruments to assess the quality of electro-mechanical and hydro-electrical parts of the MHP.
- With the advent of open bidding among pre-qualified contractors and the decision to go for the lowest bidder, several instances of poor quality of equipment have been noticed. For example, instead of using a copper plate for earthing, they used iron plates that were coated with copper; or that the jet nozzle in the turbines was made of mild steel instead of the specified stainless steel.

- DCRDC felt that the proportion of subsidy currently (40 percent) was low and needed to be increased, especially in areas where people do not have the means to bring in the rest of it.
- However, in places of relative prosperity, they felt that the current norm of 200 W/household is not sufficient and should be raised to at least 400 W/household.
- They felt that in areas of lower prosperity such as the far west, a 200 W norm was acceptable, but not in areas such as Kaski, Baglung, Lamjung, Gulmi.
- Overall, the DCRDC felt that the areas surrounding the Kathmandu Valley, and central and western Nepal, were gradually being saturated by MHPs. MHPs are successful here as these rural areas are relatively more prosperous as many are employed in the Indian, Singaporean and British armies and have regular salaries and pensions after retirement. Many others are working as skilled and unskilled laborers in Dubai and other Arab countries and send in regular remittances.
- In addition to prosperity, exposure to the outside world has stimulated their aspirations and they are willing to spend money on acquiring facilities that provide them convenience and sometimes also a source of income.

XIV. MEETING WITH DISTRICT ENVIRONMENT AND ENERGY OFFICERS

The team met with Dinesh Kr. Singh and Pritam Wangdi Lama, District Environment and Energy Officers of Panchthar and Taplejung districts. Following are the key issues that were highlighted:

- Earlier the EEOs were responsible for both pico (<10 kW) and micro hydropower plants. They had supporting staff in the form of community and social mobilizers.
- Now, EEOs are only responsible for pico hydropower and therefore do not have community and social mobilizers for support. All MHPs are now implemented with RSC support.
- Pico hydropower plants are identified during DDC planning meets and implemented by the local community with support from EEOs.
- Dinesh Kr. Singh who had earlier worked in Jumla in the mid-west region of Nepal, said that the mid-west and far-west had great hydropower potential but the people of the area were very poor and had very little exposure to the outside world and their aspirations were very low.
- Moreover, those areas had very poor or even no access and therefore, the cost of an MHP would be very high on account of transportation costs. Even repairs would cost a lot since a technician would have to take a flight from Kathmandu or Butwal to reach the place.
- Although, EEOs are also responsible for monitoring the quality and progress of MHPs, they do not have the time or the reach to do so effectively.
- Overall, it seems that EEOs (qualified engineers) are not being used well for promoting MHPs and the AEPC seems to be relying more on RSCs.

XV. MEETING WITH MANUFACTURERS AT BUTWAL

The team met with Tanka Kandel of North Engineering Company (P) Ltd and Madhav Poudel of Oshin Power service (P) Ltd. The following issues emerged from the meeting:

- North Engineering Company is in the business of MHPs since the past 20 years. In the past five years they have manufactured 100 MHPs, installed 80 MHPs and provided survey and design services for 50 MHPs.
- Today due to a large number of pre-qualified companies, competition is severe and unhealthy. With relative saturation in the central region (Kaski, Gorkha, Dhading, Baglung, Gulmi, etc.) the only source of business is cascade plants and mini hydropower (>100 kW, <1000 kW).
- There is no year round business for all companies in the micro hydropower sector.
- Quality assurance is very poor in the micro hydropower sector with only the output being tested, and the quality and dimensions of the equipment are being inspected. There are cases where the lowest bidder has offered to execute the project for an amount equal to the value of the subsidy, usually around 50–60 percent.
- Tanka Kandel advocated that the AEPC should constitute a team that would carry out random checks of manufactures at various stage of manufacturing, such as material inspections, as well as in process and final pre-shipment checks for a sample of the system that each manufacturer produces in a year.

- Based on these regular inspections, the AEPC should rate each manufacturer. These ratings should be taken into account for qualifying them for the next year/period.
- He mentioned that the vision of Odd Hofton, a Norwegian missionary was to model Nepal after the Norwegian experience in the micro hydropower sector. His dream was to have a lot of decentralized MHPs in Nepal that would connect to the grid and sell power to cities. This would ensure that rural areas with hydropower capacity would improve their economy by not only using the electricity that they generate, but also from the sale of electricity to cities. In turn, cities would develop with electricity becoming available to them to start industries. This, in many ways is the dream of practitioners in the micro hydropower sector in Nepal.

Annex 3

Details on policies and grid codes relevant to MHP

EXCERPT FROM ELECTRICITY ACT, 1992

29. **No Nationalization to be made**: (1) The land, building, equipment and structure related to electricity generation, transmission or distribution shall not be nationalized.

Provided that the land, building equipment and structure related to the generation, transmission or distribution of 1000 kilowatt or less of hydro electricity, Government of Nepal may for the extensive public use take over such property and develop and develop that itself.

Explanation: "Extensive Public Use" means the use, which serves benefits to larger population than the existing population benefited from it.

(2) Government of Nepal shall pay compensation, as prescribed, to the concerned person for the land, building, equipment and structure which is taken over by Government of Nepal pursuant to the proviso clause of Sub-section (1).

(3) The compensation payable pursuant to Sub-section (2) shall be determined on the basis of current price (after deducting wear, tear and depreciation) of the land, building, equipment and structure taken over by Government of Nepal.

30. **Purchase of Electricity Generation Plant etc.:** In case where the licensee is going to distribute electricity in an area where any person or corporate body is already distributing electricity by generating up to 1000 Kilowatt of hydro-electricity, such person or corporate body who is generating hydroelectricity up to 1000 Kilowatt if desires to sell the hydroelectricity plant, transmission and distribution line which is operated by him/her, the said licensee shall have to purchase such hydroelectricity plant, transmission and distribution line on the price (after deducting wear, tear and general depreciation) as fixed by mutual agreement.

4.4 TRANSMISSION LOSS (T-1)

4.4.1 Classification of Loss

4.4.1.1 Transmission Loss shall include Technical Loss, Non-Technical Loss and Station Loss.

4.4.1.2 Technical Loss shall be the aggregate of conductor loss, transformer loss and loss due to metering inaccuracy.

4.4.1.3 Non-Technical Loss shall be the aggregate of energy loss due to meter-reading errors and tampering of energy meters and other measurement equipment.

4.4.1.4 Station Loss is the aggregate of auxiliary consumption required for proper operation of the Grid substation.

4.4.1.5 Transmission Loss shall be derived from the following formulae:

Transmission Loss in percent = (Total Received Energy – Total Transmitted Energy – Total Station Loss) / Total Received Energy x 100.

Where:

Total Received Energy is defined as the sum of active energy received by the Grid Owner from Generators, Distributors, other Users and import at each Metering Point with adjustments, if any.

Total Transmitted Energy is defined as the sum of active energy supplied by the Grid Owner to Generators, Distributors, other Users and export at each Metering Point with adjustments, if necessary.

4.4.2 Maximum Transmission Loss

4.4.2.1 The Grid Owner shall ensure that the Transmission Loss does not exceed 4.5% of the Received Energy.

4.4.2.2 By the end of the current fiscal year and annually thereafter, the Grid Owner shall submit to the Grid Code Management Committee the Station Loss (auxiliary consumption) at each Grid substation. This shall be accompanied by full details of operating equipment, their estimated load and monthly energy consumption.

6.4 GRID OPERATING STATES AND OPERATING CRITERIA (T-1)

6.4.1 Grid Operating States

6.4.1.1 The Grid is considered to be in the Normal State when:

(a) The System Frequency is within the limits of 49.5 Hz and 50.5 Hz;
(b) The voltage at all Connection points is within the limits of 0.95 and 1.05 of the nominal value;
(c) The loadings of all transmission lines and substations are below 90% of their continuous ratings;
(d) The Grid configuration is such that any fault can be isolated from the Grid; and
(e) The Operating Margin is adequate.

6.4.1.2 The Grid is considered to be in the Alert State under any one of the following conditions:

(a) The System Frequency is outside the limits of 49.5 and 50.5 Hz but within the limits of 48.75 Hz and 51.25 Hz;
(b) The voltage at all Connection points is outside the limits of 0.95 and 1.05 of the nominal value but within 0.9 and 1.1 of the nominal value;
(c) The loadings of transmission lines and substations are at a critical stage and overloading of transmission lines and substations is imminent;
(d) The Contingency Reserve is less than the capacity of the largest synchronized generating unit or import from a single Grid interconnection, which ever is higher;
(e) A disturbance has occurred (natural calamities, such as flood, landslide, etc., or other calamities such as insurgence) which poses a threat to the operation of the Grid.

6.4.1.3 The Grid is considered to be in the Emergency State when corrective measures undertaken by the System Operator fail to arrest further degradation of the Grid without resulting in Total System Blackout and under any one of the following conditions:

(a) There is generation deficiency;
(b) Spinning reserve drops below the requirement;
(c) The System Frequency is outside the limits of 48.75 Hz and 51.25 Hz;
(d) The voltage at major Connection Points is outside the limit of 0.9 and 1.10 of the nominal value and voltage collapse is imminent;
(e) The loading level of any transmission line or substation is above 110% of its continuous rating; or
(f) Grid disturbances have resulted in cascading Outages, Islanding or Total System Blackout

6.4.1.4 The Grid is considered to be in Restorative State when Generating units, transmission lines, substation equipment and loads are being energized and synchronized to restore the Grid to its Normal State.

Annex 4:

Details on financial analysis

TABLE 4.1 | Inputs Parameters for a 100 kW MHP - Standalone

Parameter	Unit	Without subsidy	With Subsidy
Plant size	kW	100	100
Plant life	Years	15	15
Technical losses	kW	0%	0%
No. of connections	No.	800	800
Load/connection	W	120	120
Operating load domestic	kW	96	96
Operating load commercial	kW	60	60
Operations/day (domestic)	hr	6	6
Operations/day (commercial)	hr	2.5	2.5
Operations/year	days	300	300
Operations/year (commercial)	days	240	240
Capacity Utilization Factor	%	23.8%	23.8%
Capital cost	NPR million	40.00	40.00
Subsidy	50%	-	20.00
Debt	20%	8.00	4.00
Equity	80%	32.00	16.00
Interest	14%	1.12	0.56
O&M	NPR	0.80	0.80
Operators salary	NPR	22,000	22,000
Tariff domestic	NPR /month	0	0
Tariff domestic	NPR /kWh	6.00	6.00
Tariff commercial	NPR /month	0.00	0.00
Tariff commercial	NPR /kWh	8.00	8.00
Escalation	%	5%	5%

TABLE A4.2 | OverviewP/L for 100 kW MHP Standalone - with Subsidy

		Years															
Revenue	**Units**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Sales domestic	kWh		172,800	172,800	172,800	172,800	172,800	1,2,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800
Sales com-mercial	kWh		36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000
Sales	NPR million		1.32	1.39	1.46	1.53	1.61	1.69	1.78	1.86	1.96	2.06	2.16	2.27	2.38	2.50	2.62
Expenses																	
O&M	NPR million		0.80	0.84	0.88	0.93	0.97	1.02	1.07	1.13	1.18	1.24	1.30	1.37	1.44	1.51	1.58
Operator salary	NPR million		0.26	0.28	0.29	0.31	0.32	0.34	0.35	0.37	0.39	0.41	0.43	0.45	0.47	0.50	0.52
Interest on capital loan	NPR million		0.56	0.48	0.40	0.32	0.24	0.16	0.08		-	-					
Depreciation	NPR million		0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Total expenses	NPR million		2.60	2.58	2.55	2.53	2.51	2.50	2.48	2.48	2.55	2.63	2.71	2.80	2.89	2.98	3.08
	NPR million																
PBIT	NPR million		-0.72	-0.70	-0.69	-0.68	-0.66	-0.65	-0.63	-0.61	-0.59	-0.57	-0.55	-0.53	-0.51	-0.49	-0.46
Profit before Tax	NPR million		-1.28	-1.18	-1.09	-1.00	-0.90	-0.81	-0.71	-0.61	-0.59	-0.57	-0.55	-0.53	-0.51	-0.49	-0.46
PBT/ month	NPR million		-0.11	-0.10	-0.09	-0.08	-0.08	-0.07	-0.06	-0.05	-0.05	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04

TABLE A4.3 | Cash Flow for 100 kW MHP as Standalone - with Subsidy

		Years															
Cash outflow		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Investment	NPR million	20.00															
Total expenses less depreciation	NPR million		1.62	1.60	1.57	1.55	1.53	1.52	1.51	1.50	1.57	1.65	1.73	1.82	1.91	2.01	2.11
Principal	NPR million		0.57	0.57	0.57	0.57	0.57	0.57	0.57								
Total cash outflow	NPR million	20.00	2.20	2.17	2.14	2.12	2.10	2.09	2.08	1.50	1.57	1.65	1.73	1.82	1.91	2.01	2.11
Cash inflow																	
Sales	NPR million	-	1.32	1.39	1.46	1.53	1.61	1.69	1.78	1.86	1.96	2.06	2.16	2.27	2.38	2.50	2.62
Net flow	NPR million	-20.00	-0.87	-0.78	-0.68	-0.59	-0.49	-0.40	-0.30	0.37	0.39	0.40	0.42	0.45	0.47	0.49	0.52
FIRR																	
NPV NPR million	-21.62																

TABLE A4.4 | Levelized Unit Cost of Electricity @16 percent RoE for 100 kW MHP as Standalone - with Subsidy

		Years															
Discount rate		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
6%	**Total capex and expenses over life time NPR million**	20.00	5.16	5.14	5.11	5.09	5.07	5.06	5.04	5.04	5.11	5.19	5.27	5.36	5.45	5.54	5.64
	NPV of total capex and life time expenses NPR million	70.36															
	NPV of total unit generated in life time million kWh	2.15	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
	LUCE at 16% RoE NPR /kWh	2.73															

TABLE A4.5 | P/L for 100 kW MHP as Standalone - without Subsidy

		Years															
Revenue	**Units**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Sales domestic	kWh		172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800
Sales commercial	kWh		36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000
Sales	NPR million		1.32	1.39	1.46	1.53	1.61	1.69	1.78	1.86	1.96	2.06	2.16	2.27	2.38	2.50	2.62
Expenses																	
O&M	NPR million		0.80	0.84	0.88	0.93	0.97	1.02	1.07	1.13	1.18	1.24	1.30	1.37	1.44	1.51	1.58
Operator salary	NPR million		0.26	0.28	0.29	0.31	0.32	0.34	0.35	0.37	0.39	0.41	0.43	0.45	0.47	0.50	0.52
Interest on capital loan	NPR million		1.12	0.96	0.80	0.64	0.48	0.32	0.16		-	-					
Depreciation	NPR million		1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96
Total expenses	NPR million		4.14	4.03	3.93	3.83	3.73	3.63	3.54	3.45	3.53	3.61	3.69	3.78	3.87	3.96	4.06
PBIT	NPR million		-1.70	-1.68	-1.67	-1.65	-1.64	-1.62	-1.61	-1.59	-1.57	-1.55	-1.53	-1.51	-1.49	-1.46	-1.44
Profit before tax	NPR million		-2.82	-2.64	-2.47	-2.29	-2.12	-1.94	-1.77	-1.59	-1.57	-1.55	-1.53	-1.51	-1.49	-1.46	-1.44
PBT/month	NPR million		-0.23	-0.22	-0.21	-0.19	-0.18	-0.16	-0.15	-0.13	-0.13	-0.13	-0.13	-0.13	-0.12	-0.12	-0.12

TABLE A4.6 | Cash flow analysis for 100 kW MHP as Standalone - without Subsidy

		Years															
Cash outflow		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Investment	**NPR million**	40.00															
Total expenses less depreciation	**NPR million**		2.18	2.08	1.97	1.87	1.77	1.68	1.59	1.50	1.57	1.65	1.73	1.82	1.91	2.01	2.11
Principal	**NPR million**		1.14	1.14	1.14	1.14	1.14	1.14	1.14								
Total cash outflow	**NPR million**	40.00	3.33	3.22	3.12	3.01	2.92	2.82	2.73	1.50	1.57	1.65	1.73	1.82	1.91	2.01	2.11
Cash inflow																	
Sales	**NPR million**	-	1.32	1.39	1.46	1.53	1.61	1.69	1.78	1.86	1.96	2.06	2.16	2.27	2.38	2.50	2.62
Net flow	**NPR million**	-40.00	-2.00	-1.83	-1.66	-1.48	-1.31	-1.13	-0.95	0.37	0.39	0.40	0.42	0.45	0.47	0.49	0.52
FIRR	**-**																
NPV NPR million	**-46.70**																

TABLE A4.7 | Levelized Unit Cost of Electricity @16 percent RoE for 100 kW MHP as Standalone - without Subsidy

		Years															
Discount rate		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
6%	**Total capex and expenses over life time NPR million**	40.00	9.26	9.15	9.05	8.95	8.85	8.75	8.66	8.57	8.65	8.73	8.81	8.90	8.99	9.08	9.18
	NPV of total capex and life time ex-penses NPR million	126.61															
	NPV of total unit generated in life time million. kWh	2.15	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
	LUCE at 16% RoE NPR /kWh	58.90															

TABLE A4.8 | Break-even Analysis for 100 kW MHP Standalone

	Subsidy	Without subsidy
Total fixed cost NPR	1,802,200.00	3,340,400.00
Total variable cost NPR /kWh	3.83	3.83
Sale price NPR /kWh	6.34	6.34
Break-even point (kWh)	717,034	1,329,031
Break-even point (NPR)	4,549,456.10	8,432,473.17
Sales (kWh)	208,800	208,800
Increase in sales needed to reach BEP (kWh)	508,234	1,120,231
PLF at BEP	82%	152%
Current PLF	24%	24%

TABLE A4.9 | Results of Break-even Analysis and LUCE for Standalone MHPs - with Subsidy

Plant size	LUCE	PLF at BEP
20	39	122
50	36	109
100	33	82

TABLE A4.10 | Basis for Input Parameters for Financial Analysis of Grid Connected MHPs

Capital cost/kW NPR million	0.4	Based on analysis of MHP costs for Jan 1, 2012-Dec 31, 2013 & site survey
Additional capital cost for connecting to grid NPR million	4.9	Taken from quotation for Midim Khola grid connected MHP
Cost of connecting to the grid through 11 kV line NPR million/km	1.00	ASCR, Dog conductor
Subsidy from all sources	50%	Based on analysis of MHP financing & site survey
Technical losses	10%	Allowed losses in MHP
No. of household connections/kW	8	Based on site survey
Load/household connection W	120	Based on site survey
Operating load commercial kW/100 households	7.5	Based on analysis of productive end-uses from field survey
Monthly units/households-commercial	4	Based on site survey
Monthly units/households-Domestic	18	Based on site survey
Grid tariff	6.00	Based on rates agreed by NEA in its recent board meeting NPR 8.4/kWh for 5 months of year and NPR 4.8/kWh for 7 months of year

TABLE A4.11 | Incremental Analysis of Connecting 100 kW MHP to the Grid (100 percent grid availability for evacuating power to the grid)

Distance of grid extension	km	0	1	2	5	10	20
Cost of interconnection equipment including transformer	NPR million	4.90	4.90	4.90	4.90	4.90	4.90
Cost of 11kV distribution line	NPR million	0.00	1.00	2.00	5.00	10.00	20.00
Incremental capex for grid connection	NPR million	4.90	5.90	6.90	9.90	14.90	24.90
Incremental PLF (with 100% grid availability for evacuation of power to grid)	%	66%	66%	66%	66%	66%	66%
Incremental units	kWh/year	581,688	581,688	581,688	581,688	581,688	581,688
Incremental tariff	NPR /kWh	6.00	6.00	6.00	6.00	6.00	6.00
Incremental income	NPR million	3.49	3.49	3.49	3.49	3.49	3.49
Incremental O&M @3% of capex	NPR million	0.15	0.18	0.21	0.30	0.45	0.75
Incremental operating profits (100% grid availability)	NPR million	3.34	3.31	3.28	3.19	3.04	2.74
Depreciation @7%	NPR million	0.34	0.41	0.48	0.69	1.04	1.74
Interest on loan @14% on 20% of capex	NPR million	0.14	0.17	0.19	0.28	0.42	0.70
Incremental profit before taxes (100% grid availability)	NPR million	2.86	2.73	2.61	2.22	1.58	0.30

TABLE A4.12 | Incremental Analysis of Connecting 100 kW MHP to the Grid (50 percent grid availability for evacuating power to the grid)

Incremental PLF (with 50% grid availability for evacuation of power to grid)	%	33%	33%	33%	33%	33%	33%
Incremental units	million kWh/year	290,844	290,844	290,844	290,844	290,844	290,844
Incremental income	NPR million	1.75	1.75	1.75	1.75	1.75	1.75
Incremental operating profits (50% grid availability)	NPR million	1.60	1.57	1.54	1.45	1.30	1.00
Incremental profit before taxes (50% grid availability)	NPR million	1.12	0.99	0.86	0.48	-0.16	-1.44

TABLE A4.13 | P/L for 100 kW Grid Connected MHP - with Subsidy (0 km Grid Extension)

		Years															
Revenue	Units	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sales domestic	kWh		172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800
Sales commercial	kWh		45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Sales grid	kWh		581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688
Sales	NPR million		4.89	5.06	5.24	5.44	5.64	5.85	6.07	6.31	6.55	6.81	7.08	7.37	7.66	7.98	8.31
Expenses																	
O&M	NPR million		1.35	1.41	1.49	1.56	1.64	1.72	1.81	1.90	1.99	2.09	2.19	2.30	2.42	2.54	2.67
Operator salary	NPR million		0.43	0.45	0.48	0.50	0.53	0.55	0.58	0.61	0.64	0.67	0.70	0.74	0.78	0.81	0.86
Interest on capital loan	NPR million		0.63	0.54	0.45	0.36	0.27	0.18	0.09		-	-					
Depreciation	NPR million		1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41
Total expenses	NPR million		3.82	3.81	3.82	3.83	3.84	3.86	3.88	3.91	4.04	4.17	4.31	4.45	4.60	4.76	4.93
PBIT	NPR million		1.70	1.79	1.88	1.97	2.07	2.17	2.28	2.40	2.52	2.64	2.78	2.92	3.06	3.22	3.38
Profit before tax	NPR million		1.07	1.25	1.43	1.61	1.80	1.99	2.19	2.40	2.52	2.64	2.78	2.92	3.06	3.22	3.38
PBT/month	NPR million		0.09	0.10	0.12	0.13	0.15	0.17	0.18	0.20	0.21	0.22	0.23	0.24	0.26	0.27	0.28

TABLE A4.14 | Cash Flow for 100 kW Grid Connected MHP - with Subsidy (0 km Grid Extension)

		Years															
Cash outflow		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Investment	NPR million	22.45															
Total expenses less depreciation	NPR million		2.41	2.41	2.41	2.42	2.43	2.45	2.47	2.50	2.63	2.76	2.90	3.04	3.19	3.35	3.52
Principal	NPR million		0.64	0.64	0.64	0.64	0.64	0.64	0.64								
Total cash outflow	NPR million	22.45	3.05	3.05	3.05	3.06	3.07	3.09	3.12	2.50	2.63	2.76	2.90	3.04	3.19	3.35	3.52
Cash inflow																	
Sales	NPR million	-	4.89	5.06	5.24	5.44	5.64	5.85	6.07	6.31	6.55	6.81	7.08	7.37	7.66	7.98	8.31
Net flow	NPR million	-22.45	1.84	2.01	2.19	2.38	2.57	2.76	2.96	3.80	3.92	4.05	4.18	4.32	4.47	4.62	4.78
FIRR	10.2%																
NPV NPR million	8.09																

TABLE A4.15 | Levelized Unit Cost of Electricity @16 percent RoE for 100 kW Grid Connected MHP - with Subsidy (0 km Grid Extension)

		Years															
Discount rate		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6%	Total capex and expenses over life time NPR million	22.45	6.69	6.69	6.69	6.70	6.71	6.73	6.76	6.78	6.91	7.04	7.18	7.32	7.48	7.64	7.80
	NPV of total capex and life time expenses NPR million	73.97															
	NPV of total unit generated in life time million kWh	8.23	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	LUCE at 16% ROE NPR /kWh	**8.99**															

TABLE A4.16 | P/L for 100 kW Grid Connected MHP - without Subsidy (0 km Grid Extension)

		Years															
Revenue	Units	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sales domestic	kWh		172,800	72,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800	172,800
Sales commercial	kWh		45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Sales grid	kWh		581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688	581,688
Sales	NPR million		4.89	5.06	5.24	5.44	5.64	5.85	6.07	6.31	6.55	6.81	7.08	7.37	7.66	7.98	8.31
Expenses																	
O&M	NPR million		1.35	1.41	1.49	1.56	1.64	1.72	1.81	1.90	1.99	2.09	2.19	2.30	2.42	2.54	2.67
Operator salary	NPR million		0.43	0.45	0.48	0.50	0.53	0.55	0.58	0.61	0.64	0.67	0.70	0.74	0.78	0.81	0.86
Interest on capital loan	NPR million		1.26	1.08	0.90	0.72	0.54	0.36	0.18		-	-					
Depreciation	NPR million		2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35
Total expenses	NPR million		5.38	5.29	5.21	5.12	5.05	4.98	4.91	4.85	4.97	5.11	5.24	5.39	5.54	5.70	5.87
PBIT	NPR million		0.76	0.85	0.94	1.03	1.13	1.23	1.34	1.46	1.58	1.70	1.84	1.98	2.12	2.28	2.44
Profit before Tax	NPR million		-0.50	-0.23	0.04	0.31	0.59	0.88	1.16	1.46	1.58	1.70	1.84	1.98	2.12	2.28	2.44
PBT/month	NPR million		-0.04	-0.02	0.00	0.03	0.05	0.07	0.10	0.12	0.13	0.14	0.15	0.16	0.18	0.19	0.20

TABLE A4.17 | Cash Flow for 100 kW Grid Connected MHP - without Subsidy (0 km Grid Extension)

		Years															
Cash outflow		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Investment	**NPR million**	44.90															
Total expenses less depreciation	**NPR million**		3.04	2.95	2.86	2.78	2.70	2.63	2.56	2.50	2.63	2.76	2.90	3.04	3.19	3.35	3.52
Principal	**NPR million**		1.28	1.28	1.28	1.28	1.28	1.28	1.28								
Total cash outflow	**NPR million**	44.90	4.32	4.23	4.14	4.06	3.98	3.91	3.85	2.50	2.63	2.76	2.90	3.04	3.19	3.35	3.52
Cash inflow																	
Sales	**NPR million**	-	4.89	5.06	5.24	5.44	5.64	5.85	6.07	6.31	6.55	6.81	7.08	7.37	7.66	7.98	8.31
Net flow	**NPR million**	-44.90	0.57	0.83	1.10	1.38	1.66	1.94	2.23	3.80	3.92	4.05	4.18	4.32	4.47	4.62	4.78
FIRR	**-0.2%**																
NPV NPR million	**-20.06**																

TABLE A4.18 | Levelized Unit Cost of Electricity @16 percent RoE for 100 kW Grid Connected MHP - without Subsidy (0 km Grid Extension)

		Years															
Discount rate		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
6%	**Total capex and expenses over life time NPR million**	44.90	8.26	8.17	8.08	8.00	7.92	7.85	7.78	7.72	7.85	7.98	8.12	8.26	8.41	8.57	8.74
	NPV of total capex and life time ex-penses NPR million	86.78															
	NPV of total Unit generated in life time million kWh	8.23	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	LUCE at 16% RoE NPR /kWh	**10.54**															

TABLE A4.18 | Levelized Unit Cost of Electricity @16 percent RoE for 100 kW Grid Connected MHP - without Subsidy (0 km Grid Extension)

		Years															
Discount rate		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6%	Total capex and expenses over life time NPR million	44.90	8.26	8.17	8.08	8.00	7.92	7.85	7.78	7.72	7.85	7.98	8.12	8.26	8.41	8.57	8.74
	NPV of total capex and life time expenses NPR million	86.78															
	NPV of total Unit generated in life time million kWh	8.23	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	LUCE at 16% RoE NPR /kWh	**10.54**															

TABLE A4.19 | Break-even Analysis for 100 kW MHP Grid Connected

	0 km		1 km		2 km		5 km		10 km		20 km	
	Subsidy	Without subsidy	Subsidy	Without subsidy	Subsidy	Without subsidy	Subsidy	Without subsidy	Subsidy	Without subsidy	Subsidy	Without subsidy
Total fixed cost	2.47	4.04	2.51	4.12	2.56	4.20	2.70	4.44	2.92	4.84	3.38	5.64
Total variable cost/unit	1.68	1.68	1.72	1.72	1.76	1.76	1.87	1.87	2.06	2.06	2.44	2.44
Sale price/unit	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11
BEP million kWh	0.56	0.91	0.57	0.94	0.59	0.96	0.64	1.05	0.72	1.19	0.92	1.53
BEP NPR million	3.41	6	3.50	5.73	3.59	5.89	3.89	6.40	4.41	7.30	5.61	9.38
Units sold	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Units shortfall	-0.24	0.11	-0.23	0.14	-0.21	0.16	-0.16	0.247	-0.08	0.39	0.12	0.73
PLF at BEP	63.6%	104.0%	65.4%	107.0%	67.1%	110.1%	72.6%	119.5%	82.3%	136.3%	104.8%	175.1%
Current PLF	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%

TABLE A4.20 | Results of Break-even Analysis for Grid Connected MHP - with Subsidy

Plant size (kW)	Distance of Grid Extension (km)					
	0	1	2	5	10	20
20	157%	173%	191%	258%	462%	Not Applicable
50	84%	88%	92%	106%	132%	205%
100	64%	65%	67%	73%	82%	105%

TABLE A4.21 | NEA Cost of Delivery to Remote Communities

Grid extension (km.)	(HH/ sq. km)	Households served								
		200			500			1000		
		CoD (NPR)	CoG (NPR)	Total	CoD (NPR)	CoG (NPR)	Total	CoD (NPR)	CoG (NPR)	Total
0	50	13.9	7.8	21.7	13.3	7.8	21.1	12.5	7.8	20.3
	75	11.3	7.8	19.1	10.2	7.8	18.0	9.5	7.8	17.3
1	50	15.9	7.8	23.7	13.9	7.8	21.7	12.9	7.8	20.6
	75	12.9	7.8	20.7	10.9	7.8	18.7	9.8	7.8	17.6
2	50	17.9	7.8	25.7	14.7	7.8	22.5	13.2	7.8	21.0
	75	14.8	7.8	22.6	11.6	7.8	19.4	10.2	7.8	18.0
5	50	23.6	7.8	31.4	17.0	7.8	24.8	14.4	7.8	22.2
	75	20.6	7.8	28.3	13.9	7.8	21.7	11.3	7.8	19.1
10	50	33.2	7.8	41.0	20.9	7.8	28.6	16.3	7.8	24.1
	75	30.2	7.8	38.0	17.8	7.8	25.6	13.2	7.8	21.0
20	50	52.5	7.8	60.3	28.5	7.8	36.3	20.2	7.8	27.9
	75	49.4	7.8	57.2	25.5	7.8	33.3	17.1	7.8	24.9

Note: 200 households (HH) served at an average load of 100 W per HH = 20 kW; 500 HHs = 50 kW; 1000 HHs = 100 kW; CoG = cost of generation

TABLE A4.22 | Cost of Delivery - 100 kW MHP vs NEA Grid

Grid extension (km)	Distribution density (hh/sq.km)	NEA Levelized Cost of Delivery to 100 kW Load Center (NPR /kWh)	LUCE from 100 kW MHP Grid Connected - Without Subsidy (NPR /kWh)
0	50	20.33	
	75	17.26	10.54
1	50	20.64	
	75	17.57	10.68
2	50	21.03	
	75	17.95	10.81
5	50	22.18	
	75	19.11	11.22
10	50	24.10	
	75	21.03	11.89
20	50	27.95	
	75	24.87	13.24

Annex 5

Details on economic analysis

METHODOLOGY FOR CALCULATING CONSUMER SURPLUS FROM SHIFT TO ELECTRIC LIGHTING

Following IEG (2008) and UNDP (2011), a log linear functional form for demand for electricity is assumed to estimate consumer surplus from a switch to electric lighting from kerosene lighting.

$$\text{Consumer's surplus} = Qt*(Pt - Pe) + \left(\frac{K}{\eta + 1}\right)*(Qe^{\eta+1} - Qt^{\eta+1}) - (Qe - Qt)*Pe$$

With $\eta = \dfrac{\ln(Pt)-\ln(Pe)}{\ln(Qt)-\ln(Qe)}$ and $K = P/Q^{\eta}$

Pe = Price in NPR per kilo-lumen-hour for electricity = 1.63

Qe = Kilo-lumen-hours consumed per month with electricity = 270

Pt = Price in Rupees per kilo-lumen-hour for kerosene = 71.28

Qt = Kilo-lumen-hours consumed per month with kerosene = 4.44

The prevailing kerosene price of NPR 105.5/liter and the LUCE from the relevant MHP (20 kW, 50 kW or 100 kW MHP) are used in the calculation.

Kilo-lumen-hour consumption per household per month for electricity based on the average household electricity consumption of 18 kWh/month (as found in the site surveys) and a luminous efficacy of 15 lumens per watt on the assumption that the majority of micro hydropower fed households are still using incandescent lamps.

Kilo-lumen-hour consumption per household for kerosene (from Rao (2011)) describes consumption of 3 liters of kerosene/month in India to use kerosene lamps producing 37 lumens for 4 hours a day.

Based on the above, consumer surplus is calculated to be NPR 1,416/household/month or NPR 16,993/household/annum for households that are served by a 20 kW MHP.

TABLE A5.1 | Input parameters for a 10 hp (7.5 kW) Diesel Engine

Input Parameters	Units	Value
Plant size	kW	7.5
Plant life	Years	15
Capital cost of diesel generator set less 13% VAT	NPR million	0.186
Specific fuel consumption of diesel	l/hr	1.67
Economic cost of diesel	NPR /l	105.5
Hours of operation in a year	hr	600
O&M for every 250 hrs of operations	NPR	2,000
Annual O&M cost for 600 hrs of operation	NPR	4,800
Overhaul for every 6,000 hrs of operations (approx. once in every 10 years)	NPR million	0.03
Escalation	%	5%
Conversion Factors	**Diesel**	**Electric**
Energy content/unit (MJ/liter and MJ/kWh)	37	3.6
Efficiency	35%	80%
Effective energy/unit (MJ/liter and MJ/kWh)	12.95	2.88
Liter of diesel per kWh	0.22	
Liters of diesel to produce 7.5kWh	1.67	

TABLE A5.2 | Levelized Unit Cost of Electricity for 7.5 kW Diesel Engine

		Years															
	Units	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Investment	**NPR million**	0.19															
Expenses	**NPR million**		0.11	0.12	0.12	0.13	0.13	0.14	0.15	0.16	0.16	0.17	0.21	0.19	0.20	0.21	0.22
Units generated	**kWh**		4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500

Discount rate	**6%**	
NPV investment + costs	1.66	NPR million
Lifetime units generated (discounted)	43,705	kWh
Levelized Unit Cost of Electricity (LUCE)	38.09	NPR /kWh

TABLE A5.3 | Economic Analysis for 20 kW MHP

			Years													
	Units	**-**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Units of electricity generated																	
Domestic	**kWh**		34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560
Commercial	**kWh**		7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200
Total	**MWh**		41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76	41.76
Benefits																	
Consumer surplus on lighting	**NPR million**		2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
Net savings on energy cost for PEU	**NPR million**		0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
CER sales	**NPR million**		0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total benefits	**NPR million**		2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85
Expenses																	
O&M	**NPR million**		0.16	0.17	0.18	0.18	0.19	0.20	0.21	0.22	0.24	0.25	0.26	0.27	0.29	0.30	0.32
Total expenses	**NPR million**		0.16	0.17	0.18	0.18	0.19	0.20	0.21	0.22	0.24	0.25	0.26	0.27	0.29	0.30	0.32

Cash flow analysis	**Units**															Years
Cash outflow		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Investment	**NPR million**	7.80															
Total expenses	**NPR million**		0.16	0.17	0.18	0.18	0.19	0.20	0.21	0.22	0.24	0.25	0.26	0.27	0.29	0.30	0.32
Total cash outflow	**NPR million**	7.80	0.16	0.17	0.18	0.18	0.19	0.20	0.21	0.22	0.24	0.25	0.26	0.27	0.29	0.30	0.32
Cash inflow																	
Benefits	**NPR million**		2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85
Net flow	**NPR million**	-7.80	2.69	2.68	2.67	2.66	2.65	2.64	2.63	2.62	2.61	2.60	2.59	2.57	2.56	2.54	2.53

EIRR	33.69%	
Discount rate	6%	
NPV	17.73	NPR million
NPV investment + costs	9.91	NPR million
NPV benefits	27.63	NPR million
Benefits/cost	2.79	
Lifetime units generated (discounted)	405.58	MWh
Levelized Unit Cost of Electricity (LUCE)	24.43	NPR /kWh
Levelized Unit Benefit of Electricity (LUBE)	68.14	NPR /kWh

TABLE A5.4 | Economic Analysis for 50 kW MHP

			Years														
	Units	**-**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Units of electricity generated																	
Domestic	**kWh**		86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400	86,400
Commercial	**kWh**		18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Total	**MWh**		104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4	104.4
Benefits																	
Consumer surplus on lighting	**NPR million**		6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70	6.70
Net savings on energy cost for PEU	**NPR million**		0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
CER sales	**NPR million**		0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Total benefits	**NPR million**		7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04
Expenses																	
O&M	**NPR million**		0.38	0.39	0.41	0.44	0.46	0.48	0.50	0.53	0.56	0.58	0.61	0.64	0.68	0.71	0.74
Total expenses	**NPR million**		0.38	0.39	0.41	0.44	0.46	0.48	0.50	0.53	0.56	0.58	0.61	0.64	0.68	0.71	0.74

Cash flow analysis		**Years**															
Cash outflow		**0**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Investment	**NPR million**	**18.41**															
Total expenses	**NPR million**		0.38	0.39	0.41	0.44	0.46	0.48	0.50	0.53	0.56	0.58	0.61	0.64	0.68	0.71	0.74
Total cash outflow	**NPR million**	**18.41**	0.38	0.39	0.41	0.44	0.46	0.48	0.50	0.53	0.56	0.58	0.61	0.64	0.68	0.71	0.74
Cash inflow																	
Benefits	**NPR million**		7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04
Net flow	**NPR million**	**-18.41**	6.66	6.64	6.62	6.60	6.58	6.56	6.53	6.51	6.48	6.45	6.42	6.39	6.36	6.33	6.29

EIRR	35.50%	
Discount rate	6%	
NPV	44.95	
NPV investment + costs	23.39	NPR million
NPV benefits	68.34	NPR million
Benefits/cost	2.92	
Lifetime units generated (discounted)	1,013.96	MWh
Levelized Unit Cost of Electricity (LUCE)	23.07	NPR /kWh
Levelized Unit Benefit of Electricity (LUBE)	67.40	NPR /kWh

TABLE A5.5 | Economic Analysis for 100 kW MHP

			Years														
	Units	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Units of electricity generated																	
Domestic	**MWh**		172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.8
Commercial	**MWh**		36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
Total	**MWh**		208.8	208.8	208.8	208.8	208.8	208.8	208.8	208.8	208.8	208.8	208.8	208.8	208.8	208.8	208.8
Benefits																	
Consumer surplus on lighting	**NPR million**		13.18	13.18	13.18	3.18	13.18	13.18	3.18	3.18	13.18	13.18	3.18	13.18	13.18	13.18	13.18
Net savings on energy cost for PEU	**NPR million**		0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
CER sales	**NPR million**		0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Total benefits	**NPR million**		13.91	13.91	13.91	3.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91
Expenses																	
O&M	**NPR million**		0.71	0.74	0.78	0.82	0.86	0.90	0.95	1.00	1.05	1.10	1.15	1.21	1.27	1.33	1.40
Total expenses	**NPR million**		0.71	0.74	0.78	0.82	0.86	0.90	0.95	1.00	1.05	1.10	1.15	1.21	1.27	1.33	1.40

			Years														
Cash flow analysis																	
Cash outflow		**0**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Investment	**NPR million**	**4.65**															
Total expenses	**NPR million**		0.71	0.74	0.78	0.82	0.86	0.90	0.95	1.00	1.05	1.10	1.15	1.21	1.27	1.33	1.40
Total cash outflow	**NPR million**	**4.65**	0.71	0.74	0.78	0.82	0.86	0.90	0.95	1.00	1.05	1.10	1.15	1.21	1.27	1.33	1.40
Cash inflow																	
Benefits	**NPR million**		13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91	13.91
Net flow	**NPR million**	**-34.65**	13.20	13.17	13.13	13.09	13.05	13.01	12.96	12.92	12.87	12.81	12.76	12.70	12.64	12.58	12.51

EIRR	37.49%	
Discount rate	6%	
NPV	91.08	NPR million
NPV investment + costs	44.03	NPR million
NPV benefits	135.11	NPR million
Benefits/cost	3.07	
Lifetime units generated (discounted)	2,027.92	MWh
Levelized Unit Cost of Electricity (LUCE)	21.71	NPR/kWh
Levelized Unit Benefit of Electricity (LUBE)	66.63	NPR/kWh

ESTIMATION OF AVOIDED CO_2 EMISSIONS AND ECONOMIC BENEFIT FROM SALE OF CERS

Following the Nepal MHP CDM Project Design Document, the avoided emissions from an micro hydropower project (in tons of CO_2/year) and the value of the associated CERs are calculated as follows:

Annual energy generation (in kWh per year) = Installed Capacity **x** Plant Load Factor **x** 24 hours **x** 365 days

Average technical distribution losses = 10%

CO_2 emission coefficient for displaced fuel = 0.9 kg CO_2eq/kWh

Avoided CO_2 emissions = Annual energy generation / (1 – Average technical distribution losses)) **x** (0.9 kg CO_2eq/kWh) x (1/1000)

CER price = US$7 per ton of CO_2

Economic benefit = Avoided CO_2 emissions **x** CER price

Annex 6

Calculation of levelized unit cost for 20 kW diesel based generation and distribution

		Years															
	Units	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Expenses																	
Investment	**NPR million**	3.35															
O&M	**NPR million**		1.56	1.64	1.72	1.96	1.90	2.00	2.10	2.35	2.31	2.43	2.55	2.83	2.81	2.95	3.10
Units generated																	
Domestic	**kWh**		34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560
Commercial	**kWh**		7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200
Total	**kWh**		41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760

Discount rate	6%	
NPV investment + costs	24.37	NPR million
Lifetime units generated (discounted)	405,584	kWh
Levelized unit cost of electricity (LUCE)	60.09	NPR/kWh

Annex 7

Calculation of levelized unit cost for 42 kWp (20 kW) SPV based generation and distribution

		Years																				
	Units	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Expenses																						
Investment	**NPR million**	14.38																				
O&M	**NPR million**		0.29	0.30	0.32	0.33	0.35	4.67	0.39	0.40	0.43	0.45	4.77	0.49	0.52	0.54	0.57	4.90	0.63	0.66	0.69	0.73
Units generated																						
Domestic	**kWh**		34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560	34,560
Commercial	**kWh**		7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200
Total	**kWh**		41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760	41,760

Discount rate	6%	
NPV investment + costs	26.34	NPR million
Lifetime units generated (discounted)	478,984	kWh
Levelized Unit Cost of Electricity (LUCE)	54.99	NPR/kWh

Annex 8

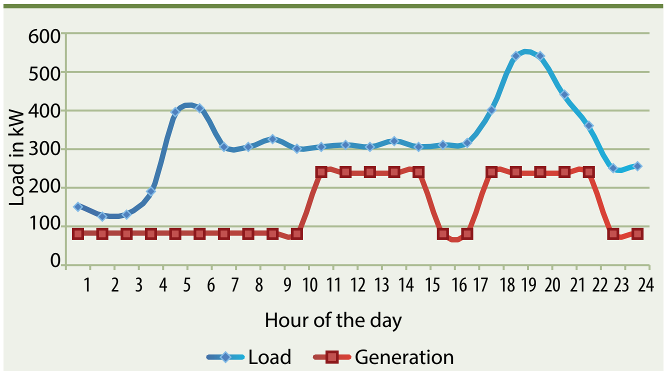
A promising mini-grid site in Phungling Bazaar, Taplejung

The AEPC has undertaken a study to implement a mini-grid project in Phungling, the district headquarters and the central market place of the Taplejung district located in the north-east remote corner of Nepal. This would be the second pilot project after the Baglung mini-grid and would provide additional information on the financial and economic viability of mini-grid systems. A brief description of the electrification possibilities in Phungling Bazaar including the Taplejung mini-grid system is provided herein.

CURRENT STATUS OF ELECTRIFICATION IN TAPLEJUNG

According to the AEPC, Phungling Bazaar has a suppressed peak hour demand of 700 kW and off-peak hour demand of 400 kW. However, these demands are not met because Phungling Bazaar is not yet receiving power from the national grid. A 125 kW "Sobuwa Khola" MHP (established in 2041 B.S.) that generates 80 kW for 24 hours and another 250 kVA diesel generator set which generates 160 kW during the 8-hour peak period is the central source of power for Phungling Bazaar. These two plants are synchronized and run by Taplejung Electricity Users Committee (TEUC), a not-for-profit organization established by the local residents and registered at the District Administration Office. The hourly power consumption and generation of Phungling Bazaar is shown in Figure A8.1.

Figure A8.1: Hourly power consumption and generation for Phungling Bazaar



The AEPC study found that the diesel generator set consumes 320 liters of diesel to operate for eight hours. With the escalation in diesel prices in the international market, operating expenses of the diesel generator set are very high. Therefore, the TEUC charges a very high electricity tariff to recover these operating costs. The tariff charged to the consumers is set at NPR 175 for the first 10 kWh, NPR 22/kWh from 10 kWh to 25 kWh and NPR 25/kWh from 25 kWh and above. Rest of the demand is supplied by distributed diesel generator sets (in isolated mode, i.e. not synchronized with the 250 kVA large generator) owned by various small-scale industries, offices, banks and other companies.

ELECTRIFICATION BY NATIONAL GRID EXTENSION

As the national grid has not reached most parts of Taplejung, the district is currently electrified by isolated MHPs with a total generating power of 1056 kW. Due to the remote location and hilly terrain, it is quite challenging to extend the national grid to

Phungling Bazaar. The NEA started the extension of its 33 kV line from Phidim, Terathum district towards Phungling Bazaar. Electric poles were extended up to Nangkholang VDC (10 km away from Phungling Bazaar) but the overhead conductors were installed only up to Bhaluchowk (40 km away from Phungling Bazaar).

Due to lack of regular maintenance and care, the installed poles and conductors have already started to age and degrade. Moreover, there is no clear plan to construct a 33/11 Substation at Phungling Bazaar (except for land allocation) to distribute the electricity from the national grid. Hence, it seems unlikely that the national grid will be extended to Phungling Bazaar for another few years. Therefore, the AEPC felt it was necessary to analyze other available options to electrify Phungling Bazaar.

ELECTRIFICATION BY ALTERNATIVE METHODS

The AEPC and RERL have considered an integrated approach to fulfill the electricity demand of Phungling Bazaar. Under this plan, they have considered implementing the following three measures side by side:

1. Upgrading the existing "Sobuwa Khola" MHP to generate at full capacity of 125 kW: In the past, an HDPE pipe was used to fix a 160 m section of the head-race canal damaged by a landslide, which has considerably reduced the discharge available for electricity generation. The AEPC has also identified that the intake structure requires some repairs to operate at full capacity. After these repairs are concluded for an estimated cost of NPR 20 million, Sobuwa Khola can generate its capacity of 125 kW.

2. Constructing a new mini hydropower plant called "Middle Phawa Khola" to generate 400 kW: The community in collaboration with the DDC initiated the development of a 244 kW "Middle Phawa Khola" mini hydropower plant. For its implementation, the Department of Local Infrastructure Development and Agricultural Roads (DoLIDAR) has already pledged 80 percent of support and the community has formed a cooperative to borrow the remaining 20 percent as loans. However, after further examination the AEPC found that the hydropower site has the potential to generate 400 kW for a total cost of NPR 112 million. Therefore, the community has decided to develop the 400 kW plant in view of the escalating power demand.

3. Interconnecting eight nearby MHPs into a mini-grid capable of supplying 660 kW of off-peak power and 492 kW of peak power: The DDC of Taplejung considered interconnecting 12 MHPs located near the Phungling Bazaar into a mini-grid. The mini-grid could supply 229 kW during peak hours after meeting the demands of distribution areas of individual MHPs and 400 kW during off-peak hours for a total project cost of NPR 130 million. However, due to the large capital required for such a small addition in capacity, the project was not found to be feasible by the AEPC. But, due to the urgent need for more power, the DDC again considered interconnecting three MHPs with the existing mini hydropower plant into a mini-grid. This mini-grid could supply 170 kW of power with an investment of NPR 15 million. Based on studies done by the DDC, the AEPC and RERL conceptualized a new design to interconnect eight MHPs into a mini-grid (see Figure A8.2). The red line shows the 26.6 km long existing 11 kV line, and the green line shows the 16.5 km long additional 11 kV line that needs to be constructed. The yellow pins show the location of the eight MHPs. The proposed mini-grid will provide 660 kW of off-peak power and 492 kW of peak power for a cost of NPR 57 million. The AEPC found this mini-grid project to be more feasible with an NPV of NPR 55 million and an IRR of 27 percent.

ESTIMATED BUDGET FOR THE INTEGRATED APPROACH

If the integrated approach is undertaken by implementing all three possibilities, it is possible to increase the electricity supply in Phungling Bazaar by 1,105 kW within two years. The breakdown of capacity addition and estimated budget is as follows.

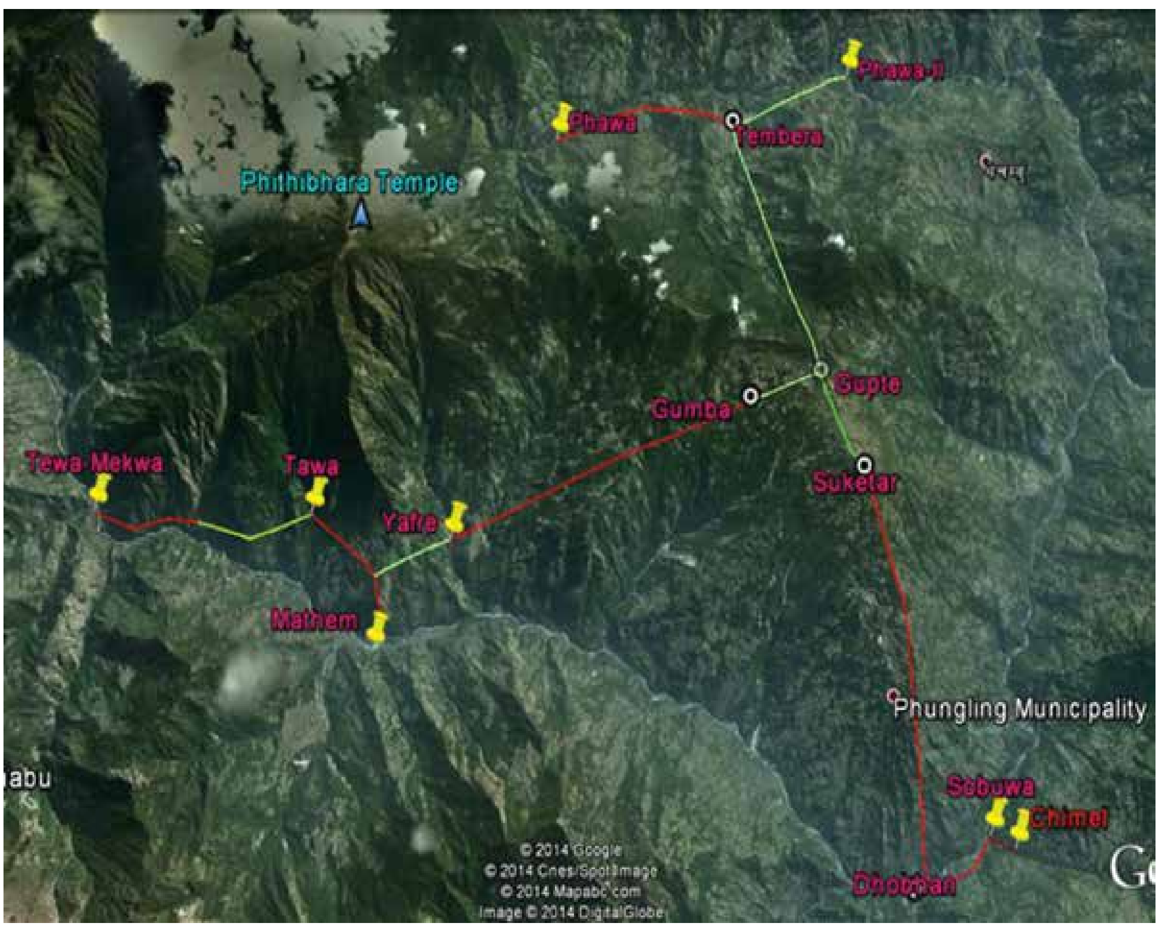
- Upgrading "Sobuwa Khola" (45 kW): NPR 20,000,000.00
- "Middle Phawa Khola" (400 kW): NPR 112,668,258.00
- Mini-grid comprising eight MHPs (660 kW): NPR 57,700,000.00

The total estimated budget for integrated power system development at Phungling Bazaar is NPR 190,368,258.00 (US$1,983,002.68).

The AEPC has determined that after the implementation of the integrated approach Phungling Bazaar will have 1,185 kW power available during the off-peak time and at least 1,017 kW of power during the peak period. According to the AEPC study, this power should be enough to supply both the off-peak and peak demands of Phungling Bazaar after two years. Moreover, by replacing the use of diesel generators with RETs, the AEPC plans to avoid NPR 1.8 million each month in diesel costs alone and reduce monthly carbon emissions by 48 TCO_2 equivalent.

A 90 kW "Chimal" MHP that is due to be commissioned in 2014 will supply power to Phungling Bazaar. This MHP can also be synchronized and interconnected to the "Sobuwa Khola" MHP.

Figure A8.2: Proposed Phungling mini-grid comprising 8 MHPs



Annex 9

Technical discussion on grid connection of MHPs

ISLANDING

Islanding is the condition when a part of the grid (in this case, the MHP's local distribution grid now connected to the national grid) becomes temporarily isolated from the national grid but remains energized by power from the MHP. Islanding can be unintentional or intentional. Unintentional islanding is a potentially hazardous condition, which occurs when the MHP fails to properly shut down during a grid disturbance. It presents a hazard to line workers who might assume that the lines are not energized during a failure of the central grid. It also denies central control over power quality and can damage utility or customer equipment at the time of reconnection, if not properly coordinated. Islanding can be detected by detecting over-/under-frequency, over-/under-voltage, rate of change of frequency, voltage phase jump, and reverse reactive power flow. Details on common relays used for detection in MHP-grid connection have been discussed later in this Annex.

On the other hand, with appropriate safety and control mechanisms, intentional islanding[89] can be used to provide reliable service to consumers of grid-connected MHPs when there is load shedding on the national grid. In the case of an MHP connected to the national grid with regular load shedding, the MHP-grid interconnection can be designed to allow the MHP to continue operating autonomously and provide uninterrupted service to local customers as well as uninterrupted revenue to the MHFG during load shedding on the national grid. This configuration is known as intentional islanding. Intentional islanding requires the following steps to be performed in the correct sequence and with appropriate timing:

- The MHP must intercept abnormal conditions on the national grid and disconnect the circuit breaker to separate its generator and islanded local distribution grid from the national grid.
- Upon disconnecting, the MHP must immediately switch from "synchronized mode" to "isolated mode" enabling the ELC to regulate the frequency. Additionally, AVR needs to switch over from power factor control mode to voltage control mode.
- The settings of various protective relays need to be different in the islanded mode, since small generators produce lesser magnitude of fault current than large generators on the national grid. Additionally, voltage and frequency tolerances need to be broader in the island mode.
- The MHP must continue to sense line voltage on the national grid. When the national grid power returns, it must initiate reconnection only after ensuring that the MHP generator is synchronized with the main grid.

89 "A Guidebook on Grid Interconnection and Islanded Operation of Mini-Grid Power Systems Up to 200 kW", Chris Greacen, Richard Engel, Thomas Quetchenbach. Lawrence Berkeley National Laboratory & Schatz Energy Research Center April 2013

FREQUENCY AND VOLTAGE CONTROL IN ISOLATED MODE

For a synchronous generator used in MHP, the frequency is determined by the rotational speed of the generator shaft connected to the turbine. Faster rotation generates a higher frequency and slower rotation generates a lower frequency. A generator's frequency depends on the balance between the flow rate of water through the turbine and the amount of electrical load served by the generator. With no load, the generator freewheels and runs at a very high speed. If the load is excessive, the generator slows down and the frequency drops below the standard.

Large and sudden changes in load or generation resources can result in frequency deviation. Therefore, in the case of an isolated MHP, the generator must control the frequency. One method of frequency control uses an electro-mechanical controller known as a governor, which opens the water supply valve in small increments to increase the water flow at the moment it detects a drop in frequency. Conversely, the governor closes the valve in small decrements when it detects excessive frequency. This negative feedback loop keeps the frequency within the specified limits under most conditions. However, governors tend to be expensive (and their responses are slow for the isolated system) for use in small micro hydropower systems.

In isolated MHPs, control of frequency is commonly accomplished by an ELC, which manages the load on the generator. By adding progressively higher loads, the generator can be slowed down until it reaches the required rotational speed for the proper AC frequency. As long as the ELC maintains this constant load, also known as the design load, the frequency can be kept within the specified limits. To maintain the design load, ELC diverts excess power to resistive heating ballasts. However, frequency control by the ELC is not adequate when the load exceeds the generating capacity of the source. If the load exceeds the generating capacity, the generator slows down, the frequency drops, and the voltage will sag. More advanced hydropower systems employ automatic relays, which drop a section of the load when the frequency begins to sag.

FREQUENCY AND VOLTAGE CONTROL IN GRID CONNECTED MODE

A small micro hydropower generator connected to the national grid does not have to regulate its own frequency. The small micro hydropower generator becomes a small part of a much larger system consisting of large generators all spinning in lockstep. As long as it is connected to the grid, it will generate power at the grid frequency, which is set by very large generators operating on the grid. The grid-connected small generator makes no attempt to regulate the frequency. It just injects current in step with the grid's frequency. Therefore, the ELC must be disabled when the MHP is grid connected.

Regulation of voltage by a grid-connected micro hydropower generator often depends on the preference of the NEA. Frequency is subject to control throughout the system by a few large generators, whereas, voltage varies from node to node throughout the system depending on the distribution of loads, generation, and the power factor correcting capacitor banks. In some locations, the NEA may prefer that an MHP operate its AVR to keep a constant power factor, which is known as "operating in power factor control mode". This helps ensure that NEA's efforts at regulating voltage through capacitor banks, load tap changers, and voltage regulators are not complicated by the MHP simultaneously adjusting its AVR to also regulate voltage. In other cases, particularly in parts of the distribution system where the NEA does not have good voltage regulation, the NEA may ask the MHP to regulate voltage, which is known as operating the AVR in voltage control mode. NEA often determines this on the basis of a power flow study, in which the system voltages, currents and power flows are modeled under minimum and maximum load conditions with the addition of the proposed distributed generators.

MODIFICATIONS REQUIRED FOR GRID CONNECTION OF MHPS

An isolated MHP with its own local distribution grid must be modified in the following ways to operate in grid-connected mode in addition to providing power to the local community during load shedding:

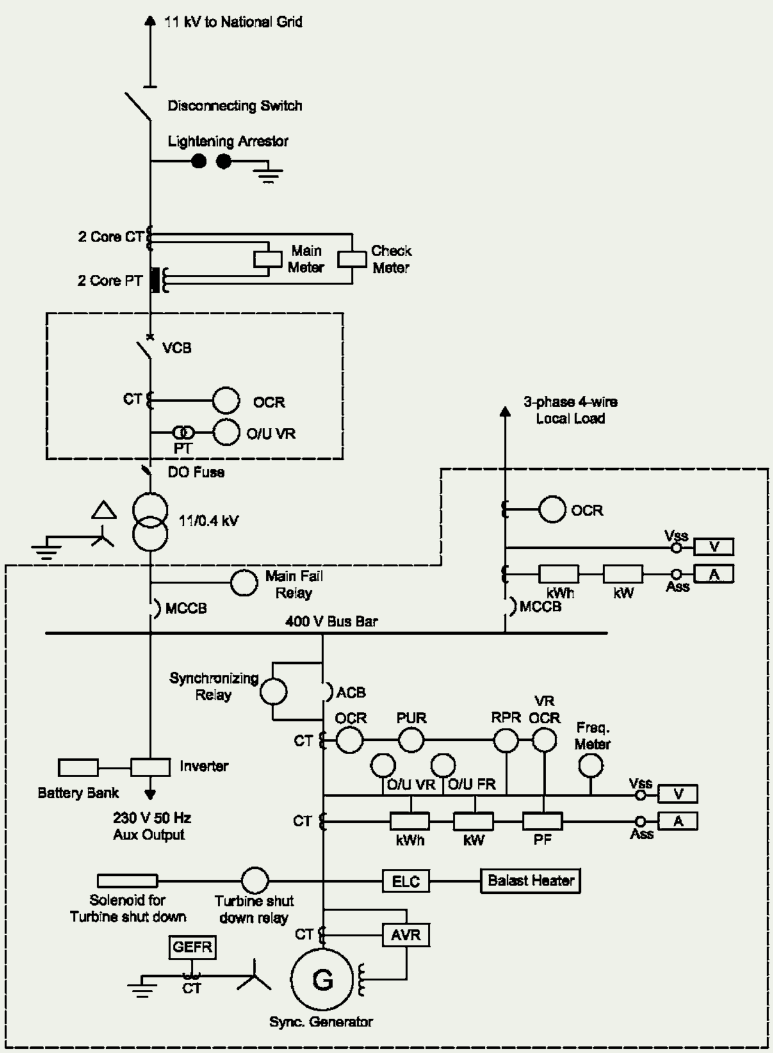
- Disable frequency control by the ELC and enable power factor control by AVR while grid connected. Conversely, enable frequency control by ELC and enable voltage control by AVR while serving the community during load shedding on the national grid (i.e., during islanding mode).
- Connect safely to the national grid by ensuring appropriate frequency and phase sequence.
- Provide quality power to the national grid with appropriate power factor, voltage and low harmonic distortion.
- Disconnect safely and quickly from the national grid during disturbances and load shedding, and reconnect after such events.

A single line diagram of an MHP with required modifications for grid connection and with provisions for islanding is shown in Figure A9.1.

CONTROL

The parallel operation of two or more generators is a complex procedure and requires an advanced control system, which is not normally included in MHPs in Nepal. A microcontroller-based control panel is the main technology that makes synchronization of MHPs with one another as well as the national grid possible. Synchronization requires measurement of

Figure A9.1: Single line diagram of MHP grid connection with islanding



electrical parameters, control with load sharing options, synchronization and protection systems.

The microcontroller-based ELC has incorporated droop setting facility that shares the load in the system proportional to the capacities of the generators. The AVR provides the required excitation voltage and current to the generator to regulate the output voltage of the generator. In the microcontroller system, the AVR is equipped with droop voltage characteristics that allow parallel operation of the generators. The ELC regulates the active power whereas the AVR regulates the reactive power in the system.

PROTECTION

For the protection of power system equipment (such as fuse, circuit breakers, contactor, relays and emergency switches) and personnel working on them, these are included in the control panel. One of the special features of the control panel is the use of relays which sense any abnormal condition in the circuit and send tripping signals to the contactors for quick and precise protection. Comprehensive metering is used to indicate power, voltage, current, power factor and ballast load. The meter displays different system parameters and status of the fault trips and system status.

COMMON RELAYS USED IN GRID CONNECTION OF MHPS

The functions of protective relays, circuit breakers, and other devices are indicated using device numbers, defined in the ANSI/IEEE C37.2 standard. These numbers are given in parentheses in this annexure.

INSTANTANEOUS/TIME OVERCURRENT (50/51)

Excessive current (overcurrent) can be caused by a fault or by excessive demand. Overcurrent relays are widely used by utilities in electrical distribution systems, for loads as well as for small generators. There are two closely related types of overcurrent relays, often combined into a single package: the instantaneous overcurrent relay (50) and the time overcurrent relay (51). The instantaneous overcurrent relay trips immediately if the current exceeds a set value; this functionality provides fast clearing of high magnitude faults. However, since motors and some other electrical loads draw a brief spike of high current when starting, relying on instantaneous overcurrent alone may result in undesired tripping when these types of loads are in use. To address this issue, the time overcurrent relay (51) allows a higher threshold for shorter periods of overcurrent. (Usually, the current threshold is inversely proportional to the event duration.)

Another function of the time overcurrent relay (51) is to facilitate relay coordination. Faults close to the generator trip the overcurrent relay quickly, preventing equipment damage. More distant faults generally result in less fault current at the generator, so the time overcurrent relay trips after a delay, allowing protective relays closer to the fault to trip first.

Small generators can supply less fault current than large generators. If the difference between the fault current and the maximum current under normal conditions is small, detection of faults can be difficult.

SYNCHRONIZING CHECK (25)

The synchronizing check relay (also referred to as a synchronism check, synchrocheck, sync-check, or paralleling relay) is a key interconnection component for synchronous generators. Before a synchronous generator is connected to the grid, the generator voltage must be synchronized with the grid voltage, both in frequency and in phase. If the generator and the national grid are not synchronized, large currents can flow at the time of connection and damage the generator. The synchronizing check relay prevents the connection to the grid from being made when the generator is not synchronized with the grid.

If automatic synchronization is used, the synchronizing check relay may be part of the automatic synchronization system. If manual synchronization is used, the synchronizing check relay prevents the breaker from being accidentally closed when the generator is not synchronized.

UNDER VOLTAGE (27)

The under voltage relay trips if the grid voltage is too low. One key function of the under voltage relay is to disconnect the generator if the national grid loses power. If the distributed generator continues to produce voltage, it could pose a hazard to utility personnel who may assume that lines are dead since the national grid is not operating. In addition, with no national grid to regulate the voltage and frequency, the distributed generator may not remain within the required voltage and frequency limits. The under voltage relay can also detect short circuits and line-to-ground faults common on long distribution lines that cause the voltage to drop.

OVER VOLTAGE (59)

Over voltage can be caused by a sudden loss of load and result in major damage to system components. On a grid-connected system, over-voltage can also indicate an islanded condition if the generation exceeds the local demand. The functions of under-voltage and over-voltage relays are often combined into a single unit (27/59).

Over voltage can also be caused by a phenomenon known as ferro-resonance, which can occur when a distributed generator becomes suddenly isolated. Ferro-resonance occurs because distribution transformers can have nonlinear inductance under certain abnormal conditions, such as a line break in one phase of a three-phase system or when distributed generation and associated capacitors are islanded. A peak or instantaneous over-voltage relay (59I) is required to detect the non-sinusoidal voltage waveform resulting from ferro-resonance.

OVER/UNDER FREQUENCY (81 O/U)

The over-/under-frequency (81 O/U) relay disconnects the generator if the frequency is out of the acceptable range. This relay helps prevent unintentional islanding; if the generator disconnects from the grid, unless the remaining load is exactly equal to the generator power output, the generator will either speed up or slow down, with a corresponding increase or decrease in frequency. Recommended over-/under-frequency protection settings for large-scale grids in Nepal are about 0.5 Hz below and 0.5 Hz above the nominal system frequency.

Rate of change of frequency may also be taken into account to avoid nuisance tripping due to a normal drift in frequency; 2.5 Hz per second is a standard allowable threshold. (This functionality is sometimes given the device number 81R.)

VOLTAGE-RESTRAINED OVER CURRENT (51V)

In the case of a short circuit between phases or from phase to ground, the initial high current spike decays as the voltage drops. If the current decays too quickly, it may drop below the threshold of the over-current relay (50/51) before that relay has a chance to operate. The voltage-restrained or voltage-controlled over-current relay (51V) allows the current threshold to depend on voltage, so that at lower voltages the relay trips at a lower current than at the normal system voltage.

Annex 10

International practices in grid connection of RETs

INDIA

India holds the RETs responsible for performing an interconnection study to determine the required equipment, impacts on neighboring customers, interconnection capacity, and measures to ensure safety of personnel and equipment. Additionally, there are no grid connection standards for RETs connecting to the grid at the distribution level. The Central Electricity Authority Technical Standards for Connectivity to the Grid (2007) mentions connectivity conditions at the distribution level. However, these standards do not specify equipment ratings and give the electric utility a great deal of discretion in deciding the design of the interconnected facility, which has created a barrier to grid connection for RETs.

Micro hydropower generation in India is largely in the hills of the Himalayas and parts of Western and Eastern Ghats. The Ministry of New and Renewable Energy Resources (MNRE) provides capital subsidy, which is channelized through state nodal agencies (SNAs). Among these currently, the Uttarakhand Renewable Energy Development Agency (UREDA) is active in the area of micro hydropower development.

The Alternate Hydro Energy Centre (AHEC) that is located in the Indian Institute of Technology, Roorkee, Uttarakhand provides technical support to UREDA to roll out MHPs in the state. Specifically, the AHEC provides support in preparation of DFS, technical supervision and equipment testing. Currently, there are five MHP manufacturers in India that are active in supplying MHP equipment.

During the late 1990s and early 2000s, UNDP-GEF supported the MNRE to roll out the hilly hydropower program that aimed to help remote hill communities access electricity through the systematic development of micro/mini and small hydropower potential in selected hilly states in the country. A terminal evaluation[90] found that although the project aimed to set up several standalone hydropower projects, most of the projects ended up as grid connected SHPs with several projects having commercial investors. However, the project did give a huge fillip to the small hydropower sector in the country and helped develop an active small hydropower manufacturing, installation and development industry.

Unlike SHPs, micro hydropower projects did not attract the attention of commercial investors since they were not very attractive financially and were often plagued by low PLFs and low revenues. Eventually, micro hydropower projects got limited to being implemented by NGOs and local communities with generous capital subsidy from the MNRE and

[90] Terminal Evaluation and Impact Assessment of The UNDP/GEF Project – Ind/91/G-31 – Optimizing Development Of Small Hydel Resources In The Hilly Regions Of India, Indian Institute of Public Administration, New Delhi

the SNA. UREDA, for example offers 70 percent to 80 percent capital subsidy and supports only local communities in setting up micro hydropower projects.

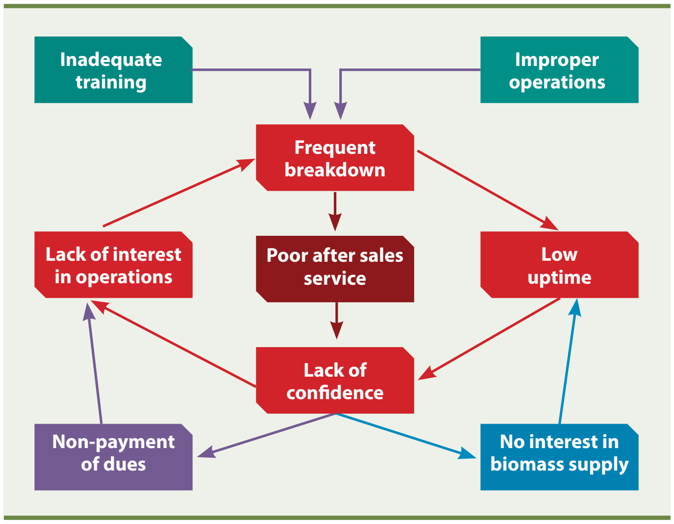
However, a key feature of UREDA's micro hydropower program has been the use of metering and the encouragement given to grid connectivity once the grid enters the service area of the micro hydropower project. Ramgad is a village in Uttarakhand that got electricity supply with a 100 kW MHP in 1995. UREDA provided bulk of the funds for setting it up. Until 2004 power supply was through unmetered connections, when the grid was extended to the area. UREDA helped the Ramgad Urja Samiti that was managing the MHP to connect to the grid. Each family put in INR 10,000 as contribution to partly finance the cost of grid connection. Under a tripartite PPA with the Uttarakhand Power Corporation Ltd., the Ramgad Urja Samiti gets 25 percent of the revenue while UREDA gets 75 percent of the revenue from the sale of power to the grid.

Today, there are several micro/mini hydropower plants that are connected to the grid. Key problems faced by them relate to quality and reliability of the grid for evacuating power and unattractive tariffs offered.[91] However, overall, the micro hydropower sector in India is tiny and has not been able to attract significant commercial interest in either ownership/ operations of MHPs or in MHP manufacturing. Interestingly, some of the micro hydropower installers in India reported having purchased turbines from Nepal.

VILLAGE ENERGY SECURITY PROGRAMME

During the first decade of this century, MNRE piloted the Village Energy Security Programme (VESP) in about 200 locations in the country. The key feature of the programme was total energy security to off-grid villages. This included not only the provision of electricity access through local generation using biomass gasifiers or diesel generating sets run on bio-oil but also biogas and improved cookstoves for cooking applications. Also for the first time, the MNRE decided to work in close collaboration with NGOs as implementing partners rather than work through the SNAs. More significantly, the program envisaged that the biomass gasifiers would be owned and operated by the local community represented by Village Energy Committees (VEC). A key task for the NGO (implementing partner) was to help in the formation and nurturing of these VECs. In many aspects, this arrangement is similar to the role that an RSC plays. But a key difference is that the community has a significant equity (sweat and cash) in the micro hydropower sector in Nepal, but in the VESP, with 90 percent coming as subsidy from the MNRE and the rest often from state governments, the local community was handed an asset for which they had virtually paid nothing. A World Bank study[92] found that VECs were unsuccessful largely because the community had little stake in the asset (usually a biomass gasifier) and the technology was not easy for the remote communities to handle, especially with poor after sales service from distantly located gasifier manufacturers. Figure A10.1 below depicts the typical problem cycle in these projects.

Figure A10.1: Problem cycle of biomass gasifiers for rural electrification



[91] Cost of generation varies with the size of the plant. Larger plants enjoy considerable scales of economy. But energy regulators routinely club micro/mini hydropower plants with SHPs (usually up to 5 MW) while determining tariff on a cost+RoE basis. This tends to make the tariffs a little less attractive to MHPs.

[92] India: Biomass for Sustainable Development: Lessons for Decentralized Energy Delivery Village Energy Security Programme, World Bank, 2011

It is interesting to note that the micro hydropower program has successfully used the very same VEC in the form of MHFGs to manage MHPs in remote locations. A key enabler for this is the demand driven process of micro hydropower with the community having a very significant financial stake in setting up the MHP.

BIOMASS ENERGY FOR RURAL INDIA: UNDP-GEF AND GOVERNMENT OF KARNATAKA

Biomass Energy for Rural India (BERI), a project implemented in the Government of Karnataka, a state in south India with support from UNDP-GEF was based on mobilizing local communities to build a supply chain for biomass fuel to be used in community owned and operated biomass gasifier power plants that are connected to the electricity grid at distribution voltages (11 kV). For the first time in India, a community owned and managed biomass gasifier power plant (3 x 100 kW + 1 x 200 kW) was connected to the grid at 11 kV. Subsequently, a PPA was also signed with the distribution company (Bangalore Electricity Supply Company) for purchase of power from the power plant. Although, the plant was originally designed for supplying power to the nearby villages, it was soon realized that with large irrigation pumping loads in the area, the plant would not be able to meet the demand. Therefore, a decision was taken to connect it to the grid and operate it as an IPP. However, due to the instability of the 11 kV rural feeder line and also several technical issues with the biomass power plant, synchronization of the plant with the grid proved elusive for long periods of time. Therefore, in the context of MHPs being grid connected in Nepal, a significant lesson is quality of power from both the generating plant and the grid is important to ensure evacuation of power to the grid.

SRI LANKA

Sri Lanka was an early leader in grid-connected MHPs, majority of which were originally built as isolated systems to power tea plantations. However, grid capacity constraints have recently limited the ability of existing MHPs to connect to the grid. Sri Lanka's national electricity utility, Ceylon Electricity Board (CEB), addressed this issue in one instance by subsidizing half the cost of grid upgrades for a group of MHPs willing to connect to the national grid.

Recent regulatory changes and the publication of a project approval guidebook for grid connection of new and existing renewable energy projects have streamlined the process for bringing new renewable generation online. Sri Lanka's Sustainable Energy Authority prepares the guidebook, which lays out a process in which an applicant first registers a project and performs a pre-feasibility study. The concise guidebook provides detailed instructions for the entire process, application forms, and application process flowcharts in a single document. Additionally, checklists specific to the energy resource type (biomass, hydro or wind) list the information required in the pre-feasibility study.

TANZANIA

The Government of Tanzania through the Ministry of Energy and Minerals is establishing a framework for developing small power projects in collaboration with various international development partners. The framework aims to accelerate electricity access by promoting development of small power projects among local and foreign private investors. It includes "Standardized Power Purchase Agreement" and "Standard Tariff Methodology" applicable between the developer of renewable energy projects with capacity ranging from 100 kW to 10 MW and buyers such as the national grid or local isolated grids. The framework, which is being developed pursuant to Tanzania's Electricity Act (2008), opens the possibility of implementing rural electrification projects and aims to reduce negotiation time and cost.

THAILAND

In Thailand, 1,200 MW of renewable electricity generation projects are online and an additional 3,700 MW of projects have signed PPAs. However, Thailand recently made the process of national grid connection more cumbersome by introducing subjective approval steps and requiring applicants to demonstrate financial soundness by posting refundable deposits. These changes have slowed down the previously dynamic renewable energy market.

DENMARK

Denmark has set a FIT requiring electricity utilities to buy all power produced from RETs at 70 percent to 85 percent of the consumer retail price of electricity in the given distribution area. RETs are provided open and guaranteed access to the national grid such that the national grid is required to finance, construct, interconnect, and operate the transformer, transmission and distribution infrastructure for RETs. Additionally, a general carbon tax is levied on all forms of energy, which adds approximately EUR 0.013/kWh of additional income for RETs.

To streamline the grid connection procedure of RETs, the Danish Energy Authority provides "One Window" services for renewable energy tenders, site approvals, environmental impact assessments, construction, operation, and licensing of generating plants.

AUSTRALIA

Australia passed the Renewable Energy Act in 2000 with a target to add 9,500 Giga-watt-hours of renewable energy per year. The Act includes a framework titled the Mandatory Renewable Energy Target (MRET) scheme to create, trade, and surrender Renewable Energy Certificates (RECs). This scheme allows renewable energy credits to be created by renewable energy generators and traded to electric utilities (that may have high renewable energy production costs) to meet their renewable energy purchase obligations.

CHINA

China passed the Renewable Energy Law in 2006 with the aim of increasing the use of renewable energy up to 10 percent by 2020. The law requires transmission companies to provide grid connection to RETs and to purchase power from these facilities. In addition, it offers financial incentives such as discounted lending and tax preferences for renewable energy projects. The tariff for renewable energy is set by the National Development and Reform Commission at the national level and is spread out among consumers.

GERMANY

Germany passed the Renewable Energy Sources Act in 2004 to increase the share of renewable energy sources in power supply to at least 12.5 percent by 2010 and 20 percent by 2020. The Act prioritizes as well as outlines procedures for connecting RETs to the national grid, and sets standards for purchase, transmission, and payment for such electricity by the national grid. The Act also includes FITs and ascribes responsibility of various interconnection costs.

KENYA

Kenya began offering FITs to encourage renewable energy development in 2008. However, so far there has been little project development in response. Efforts are under way for Kenya Power, the national electric utility, to introduce new interconnection procedures. Under this scheme, Kenya Power would respond to an initial Expression of Interest from RETs to connect to the national grid. A simple one-page document would inform the RET of Kenya Power's opinion on the proposed grid connection and alert the RET of any potential problems with the project from the national grid's perspective.

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