Policy implications for up-scaling of off-grid solar PV for increasing access to electricity in rural areas of Nepal: Best practices and lessons learned

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ABSTRACT

Nepal has huge potential of hydro and other renewable energy resources including solar energy. However, only 70% of the total population have access to electricity despite the long history of hydropower development in the country. Still more than 37% population in rural areas and around 73% population in Karnali Province, one of the least developed provinces, are living without access to electricity despite taking several initiatives and implementing various policies by government supporting electrification in off-grid rural areas. Government together with donors and private sector has extensively been promoting the off-grid solar photovoltaic (PV) echnology in un-electrified areas to increase electricity access. So far, more than 900,000 households in rural areas of Nepal are getting electricity from stand-alone solar PV systems. However, there are many challenges including financial, technical, institutional, and governance barriers in Nepal. This study based on extensive review of literatures and author's own long working experiences in renewable energy sector in Nepal, shares the best practices and lessons of off-grid solar PV for increasing access to electricity in rural areas of Nepal. This

study suggests that flexible financial instruments, financial innovations, bundling of PV systems for concentrating energy loads, adopting standards process, local capacity building, and combination of technology, financing and institutional aspects are a key for enhancing effectiveness of solar PV technology in rural areas of Nepal.

Keywords: Solar PV, Off-grid, Electricity, Nepal

Introduction

Background

Energy is basic need of the human being and it is the engine of economic growth.[24] Demand of energy is significantly increased around the world both for rapid economic growth, and access to billions of population. Furthermore, the improved living standards of people and economic development are indirectly or directly linked to increasing use of energy. The economic development and prosperity of human beings are heavily dependent on an adequate supply, security, efficient use and affordability of energy. Without access to energy, there is very little chance of reducing the poverty and growth of development.[18]

Despite the high potential of renewable energy resources in Nepal, the country is heavily dependent on traditional energy sources such as fuel-wood, agricultural and forest residues, which constitute about 78.4% of national energy consumption in 2015/16 as shown in Figure 1. The remaining energy consumption comes from imported fossil fuels approximately 10.8% from petroleum products, 4.6% from coal and 3.7% from electricity mainly hydro-power. The contribution of modern renewable energy including solar energy was 2.5%.

As shown in Figure 2, the residential sector is the highest energy consuming sector (80%), followed by industry (8%), transport (7%) and commercial (4%). The residential and transportation sectors are dependent on imported fossil fuels resulting in, inter

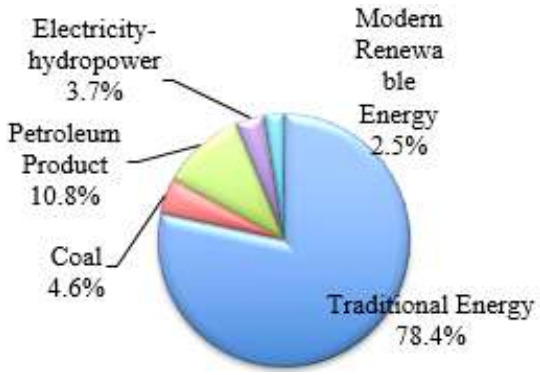

Figure 1. Nepal's Energy Consumption by Sources, 2015
Source: Ministry of Finance, Nepal, 2017

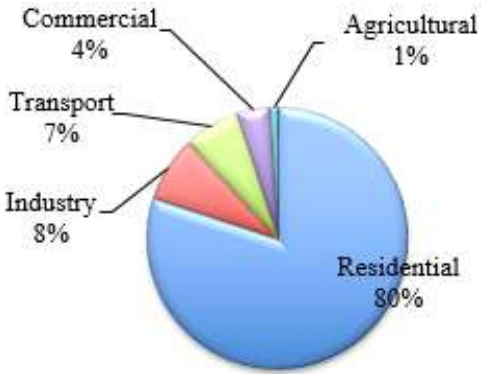

Figure 2. Nepal' Energy Consumption by Sector, 2015
Source: Ministry of Finance, Nepal, 2017

alia, an environmental degradation, and increasing energy insecurity in the country. In Nepal, power sector is dominated by hydropower with installed capacity of 1,029 MW (almost 90%), out of 1,142 MW[18] as of March 2019. But, the current demand of electricity is more than this. The total generation also includes the power generation from solar PV (27 MW) mostly off-grid solar PV in rural areas of Nepal.[11] Almost 70% of the population have access to electricity in Nepal, 63% in rural areas and about 96% in urban areas.[12] However, around 37% of the rural population are still living without access to electricity. Nepal is a country with a large number of remote rural areas, and extension of national grid to those areas is very expensive, financially unattractive, and needs huge investment and takes long time for providing the electricity. Poverty is also rampant in rural areas (27%) as compared to urban areas (15%), and very high in mountainous areas (42%).[19] However, the decentralized renewable energy technologies, mainly micro/mini hydropower (less than 1000kW), solar energy, biomass energy and wind energy, can be the cost effective sources of energy if local resources including expertise are properly and efficiently used. The promotion and development of renewable energy in rural areas of Nepal can also contribute for socio-economic development, inter alia, improving the quality of rural life through creating additional job opportunities, improving and accessing to education and health, and increasing the income from productive use of energy. In addition to these, renewable energy can contribute for reduction of the greenhouse gas (GHG) emission, increasing the adapting capacity to climate change and improving air pollution. The renewable energy particularly solar energy might be the lower cost option in rural areas with scattered settlements and low energy load.

Nepal being located in favorable latitude receives good solar radiation. The average solar radiation varies from 3.6–6.2 kwh/m^2/day, 300 days as annual sunny days with 2,100 hours as annual number of sunny hours and 6.8 sunny hours per day.[22] The peak solar radiation is observed from April to July and the least solar radiation is observed from November to February.[5] The development of solar energy is favorable in many parts of the country. The generation of solar power depends on the area and intensity of solar radiation. According to the UNEP-GEF 2008 report for solar and wind energy resource assessment in Nepal, the total potential of solar power in urban area with grid access is 2,100 MW by considering 2% of the total suitable land area of the country.[21] Among the decentralized energy options, solar energy particularly solar PV is one of the proven, matured and potential energy technologies for increasing access to electricity in rural areas of Nepal. This paper thus focus on the off-grid solar PV for electricity access in rural areas of Nepal.

Scope and Objective

According to 2011 census, the total population of Nepal was 26.5 million. Out of this, urban population was 17% while rural population was 83%.[7] Majority of people are living in rural areas with minimum or basic infrastructure and facilities like road, drinking water, education and health. Most of the rural areas are located in very remote with 5–18 days walk.[6] In the rural areas more than 37% of the populations are deprived of electricity.[12] The cost of the grid

electricity is very high and is required huge investment as well as long time, and local micro/mini hydro power plants are not feasible in many areas. The biogas for cooking and also lighting is not feasible in high hilly region due to low production of biogas because of low temperature. The wind and biomass resources are not available in most of the areas and are new technologies to rural areas of Nepal. This will compel to the country to search for other off-grid energy technologies like solar PV for electricity supply. Due to the ease of installation, modular size and small weight, solar PV seems to be the most viable renewable energy technology in rural areas. Even the individual house can decide to install a solar PV system for electricity supply based on his or her financial situation and demand of electricity. Furthermore, the need for little repair and maintenance, and high reliability of operation makes the solar PV best suited for rural areas. Stand-alone solar PV system can provide the household electricity for lighting and operation of small appliances. In the past, Nepal was facing the 14 hours of load shedding problem in the grid connected areas, and at present although there is no official load shedding, the electricity supply is not regular and reliable in urban areas. So, the stand alone solar PV technology has become the reliable back-up power supply in urban areas as well.

The main objective of this article is to provide the information on some of the best practices and lessons learned from the dissemination of stand-alone solar PV for increasing access to electricity in off-grid rural areas of Nepal.

Off-Grid solar PV in rural areas of Nepal

History of off-grid solar PV development

Nepal is one of the fortunate countries with enormous hydro resources with an estimated potential of more than 85,000 MW and also huge potential for solar energy with an average radiation of 4.7 kwh/m^2/day.[17] But these resources have not been exploited properly. Even though solar energy has been used in Nepal for many years particularly for heating water and drying agricultural products, the use of solar energy for rural electrification is not very long. The study shows that the electricity generation from solar PV was first in 1983 for rural households' electrification with support from Government of France in Simikot, Gamghadi, and Kodari/Tatopani of Nepal with the total capacity of 130 kWp for 500 households.[23] But the first stand-alone solar PV system programme was implemented and supported for 67 households (each with 36 Wp capacity) in Pulimarang village, Tanahun district which is western part of Nepal in 1994 with support from Solar Electric Light Fund, USA and initiated by Centre for Renewable Energy, a Nepalese NGO.[8,9] Since then, popularity of solar PV system has and realized that solar PV technology could be one of the good options for rural electrification in Nepal. A standard 36 Wp solar PV system can provide electricity to power 3-4 light bulbs, a radio and a black and white TV, which is more than enough in the rural typical house.[8,9] The Figure 3 shows the installation of stand-alone solar PV systems in rural households in Nepal. Almost every house has solar

Figure 3. A good example of solar PV systems installed for electrification in rural houses of Nepal

PV system with similar capacity (36 Wp), which is standard size in rural areas of Nepal in the past. As shown in Figure 3, majority of the houses have solar PV system at rooftop both for security reason and capturing better solar radiation.

In 1995, a local company, Lotus Energy and the US Bureau of Oceans and International Scientific Affairs initiated a solar PV electrification programme for supporting 49 solar PV systems.[9] The Agriculture Development Bank of Nepal (ADB/N) supported for financing renewable energy technologies including stand-alone solar PV system till 1996, the year of establishment of Alternative Energy Promotion Centre (AEPC), a government institution responsible for promotion and development of alternative and renewable energy technologies in Nepal. Government of Nepal (GoN) for the first time provided the subsidy of 50% in 1996 but not exceeding NRs. 15,000 (approx. 300 USD with exchange of 1 USD~about NRs. 50 at that time), and similarly, the then Ministry of Local Development, Nepal also supported 53 solar PV systems with 70% subsidy for rural electrification in 1997/98.[9] ADB/N and AEPC both supported solar PV systems installation till 1999. Danida started to launch the Energy Sector Assistance Programme (ESAP) for the first 5 years in 1999 through AEPC, where solar energy programme was also a major programme. GoN for the first time formulated and implemented a subsidy policy for renewable energy in 2000. One of the studies shows that by end of 1999, more than 2,600 stand-alone solar PV systems were installed in Nepal.[8] Since 2000 with implementation of first national subsidy policy for renewable energy and initiated by AEPC, there have been rapid increased of installation of solar PV systems in rural areas of Nepal with focus in remote and very remote areas as part of off-grid rural electrification with support from GoN and external development partners including Denmark, Norway, Germany and DFID (UK). Since 2000, all the solar energy activities carried out through or in coordination with AEPC.

Current situation of off-grid solar PV

Despite the very favorable condition of solar energy in Nepal with high solar radiation, it has not succeeded in widespread dissemination of solar PV with higher capacity. Nepal's solar PV particularly for the rural households' electrification is largely dependent on direct financial support either from international donors or government as subsidy. The data of the government agency, AEPC, shows that the population with access to electricity from stand-alone solar PV is 6.25% out of 9.75% population having access to electricity from small-scale renewable energy technologies.[1] The number of stand-alone solar PV installed in off-grid rural areas with government subsidy (funding from both GoN and Donors) through AEPC has reached to 911,097 till mid July 2019.[1] In addition to this, the number of stand-alone solar PV disseminated in urban areas with grid connected is 21,144 till same time.[1] So with one household one solar PV, the number of households having electricity from solar PV in rural areas is 911,097. This figure is the data of solar PV systems supported with government subsidy through AEPC from 2000/01 to 2018/19.

The number of stand-alone solar PV systems installed in 2000/2001 was 1,160 which was the lowest, while the number continuously increased by 2004/2005 (17,887 nos.) as shown in Figure 4. From 2005/06 to 2006/07, number of installed systems decreased drastically due to suspension of subsidy funding from donor (Danida) due to political situation (takeover of power by then King) of Nepal.[6] But again, the number of systems increased from 2007/2008 to 2008/2009 due to implementation of the new energy programme, second phase of Energy Sector Assistance Programme (ESAP II) supported by GoN, Danida and Norway with huge target, 90,000 of stand-alone solar PV and 140,000 of small solar PV for 5 years.[6] In 2009/2010, installation was slow due to delay in revision of renewable energy subsidy policy. In 2012, a new but expanded programme of

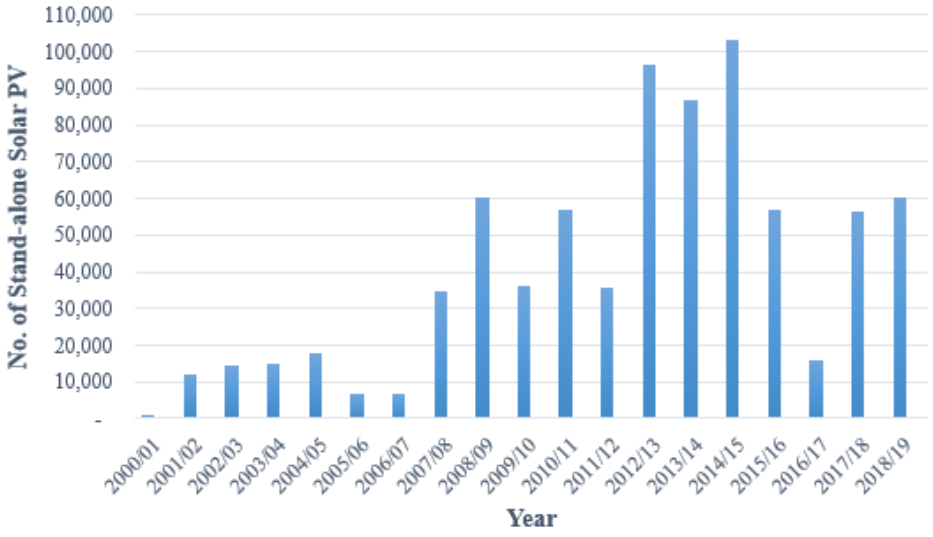

Figure 4. Year-wise installation of stand-alone solar PV systems in rural areas of Nepal

Source: https://www.aepc.gov.np/statistic/solar-home-system and compiled from AEPC Progress Report 2017/18 and 2018/19

an ESAP, National Rural and Renewable Energy Programme (NRREP) was launched where dissemination of solar PV systems was the major component of the programme. The highest number of stand-alone solar PV systems (103,161 nos) was installed during 2014/15 because of new subsidy policy and growing number of private solar companies. The number of solar PV systems decreased drastically in 2016/2017 due to phasing out of the donors' support. However, solar PV can also contribute significantly to provide the electricity to the majority of population around 73% in Karnali Province of Nepal, one of the least developed province, and around 43% population in Far Western Province having without access to electricity.[11]

The demand of solar PV in rural areas has also been decreasing in recent years due to number of reasons, inter alia, lack of funding for subsidy, preferences of local communities for micro/mini hydropower in the areas of water resources, extension of grid, migration of people from rural to urban areas for better opportunities. The robust technical design, testing of major components of solar PV, quality control, field monitoring, heavy penalty to the installer companies, mandatory after-sale service, and trained solar technicians have led to success of dissemination of stand-alone solar PV systems in rural areas of Nepal. However, there are many issues for dissemination of subsidized off-grid solar PV systems in rural areas of Nepal such as high cost of monitoring, installation in already electrified or to be electrified areas in near future, timely repair and maintenance by the installer companies, installation of non-tested components, double claiming of subsidy amount by companies, selling of installed systems by users, lack of seriousness by companies in providing after-sale service within warranty period etc.

Government initiatives and key policies

The importance of solar PV for rural electrification was realized after establishment of Alternative Energy Promotion Centre (AEPC) in 1996. Before that some international non-governmental organizations, non-governmental organizations and few private companies were involved in piloting solar PV projects in some parts of Nepal. In 1996, Government of Nepal (GoN) through Agricultural Development Bank/Nepal (ADB/N) provided subsidy (50% of the total cost) for limited number of solar PV systems in rural areas of Nepal.[9] In 1997/98, the Ministry of Local Development provided the 70% subsidy to install solar PV systems. Even though AEPC was established in November 1996, it supported solar PV systems since 1997/98 with very limited targets and budget. After Danida supported the Energy Sector Assistance Programme (ESAP) in 1999 and GoN formulated the national subsidy policy in 2000, the solar PV programme was implemented nationwide in un-electrified rural areas and increased rapidly.[8] GoN again revised the subsidy policy for renewable energy in 2006 and GoN, Danida and Norway jointly launched the second phase of ESAP in 2007 for the five years with huge targets of solar PV systems (solar PV systems: 90,000 nos. and small solar PV systems: 140,000 nos.).[6]

The number of private companies and few banks involved in the promotion of solar PV systems together with GoN and donors. The installation of solar PV systems increased further since 2012/13 after launching of the expanded renewable energy programme, NRREP, with support from GoN and

Table 1. Subsidy for stand-alone solar PV system in Nepal

Capacity range	Subsidy amount in Nepalese rupees (NRs)			Remark
	Very Remote Areas (A)	Remote Areas (B)	Areas other than (A) and (B)	
10–20 Wp (per household per system)	5,000 (~44 USD)	4,800 (~42 USD)	4,500 (~40 USD)	The exchange rate for 1 USD ~ NRs.113 as of 17 Jan. 2020
50 Wp or more (per household per system)	10,000 (~88 USD)	9,000 (~80 USD)	8,000 (~71 USD)	

Source: Ministry of Population and Environment, 2016

number of donors (Danida, Norway, Germany, and United Kingdom) in 2012 for the five years, and revision of subsidy policy in 2013. GoN has been providing direct financial support as subsidy for installation and also exemption of taxes (value added and custom duties) while importing the components of solar PV systems. GoN has also plan of generating additional 127 MW electricity from solar PV system and providing the electricity to additional 5% population during 15th Five Year Plan (2019/20–2023/24) from micro hydro, wind energy and solar PV.[15] Some of the key policies as mentioned in the Nepal's 15th Five Year Plan: Approach Paper[15] are as follows:

- Promotion, development and expansion of solar energy and maximum utilization of produced electricity.
- Promotion of solar PV technology in the areas not covered from national grid.
- Support to connection of solar PV to the grid.
- Resource assessment and data collection of solar energy.
- Strengthening testing and standardization of components of solar energy.
- Creating conducive environment for the investment in and providing soft loan from banks and financial institutions to RETs including solar PV.
- Mobilization of national and international climate financing resources for the promotion of RETs including solar PV.

The current subsidy policy for renewable energy in Nepal states that subsidy will be given for generation of electricity from solar energy in the areas not covered by national grid or other renewable energy sources.[14] The current subsidy for off-grid solar PV systems is as shown in Table 1. The Table 1 shows the subsidy amount for various capacity of solar PV systems in Nepal. The more subsidy amount is provided to higher capacity. But the percentage of subsidy amount as compared to the cost is lower with increased of capacity with the assumption that people who can afford can install higher capacity. Furthermore, the table shows that more subsidy is provided in very remote areas as compared to remote and other areas (less remote areas.).The percentage of subsidy for lower capacity and more remote areas is higher so, that even low income household can install solar PV system.

Best practices and lessons learned

In Nepal, solar PV technology has been one of the most successfully disseminated renewable energy technologies for enhancing energy access in un-electrified rural areas. So far, more than 900,000 households in rural areas are getting electricity from solar PV technology for lighting and operation of

household appliances (TV, radio etc.). Government, donors and private sectors have been instrumental in dissemination of solar PV technology in massive scales over the short period of time. The demand based dissemination approach led by private sector, selection of private companies based on performance, service delivery, business capacity and skill human resources, enforcement of strict penalty and reward system, standardization, testing and certification of products, mandatory provision of after–sales service by the installer companies, proper system sizing and technical design, installation from certified technicians, provision of subsidy based on remoteness and size of solar PV system, access to credit financing, provision of quality assurance and third party monitoring of installed systems, repair and maintenance of the installed systems, capacity building of private sector, users' awareness for use and maintenance of the PV systems etc. have led to success of solar PV for rural electrification in Nepal. Due to active involvement of many private companies in the promotion of solar PV in Nepal, potential users have opportunities for negotiation for the price, quality, free transportation of the systems, after sale services and free maintenance.

A study on socio–economic impact of users of solar PV systems carried out by an independent consultant in 800 users in Nepal shows that users preferred solar PV technology for lighting (100%), charging of mobile phones (56%), operation of radio (50%), operation of television (35%), operation of cassette player (10%) and VCD/DVD (8%).[2] Study further finds that solar PV systems have positive impact on increasing access to information (through TV, radio, mobile phone etc.), increased in education both in performance and enrollment (spending more time for study due to better light, less drop out from school etc.), increased in income mainly from retail shops, tea shops etc. (households started business after having solar PV due to light, information from TV and radio etc.) and increased the business time at night, improved in health due to reduction of kerosene and firewood for lighting, and improved in security due to light at night (less crime at night because of recognition of criminals and culprit). It was also found that households with higher income, educated and having access to information about technology have installed the solar PV systems. The study further shows that majority of households prefer solar PV with capacity range of 19–50 Wp (76%), followed by less than 18 Wp (15%) and more than 50 Wp (9%).[2] These shows that even the small size of solar PV in rural areas can have huge positive impact for improving the quality of life of the rural populations.

According to recent news published in national daily newspaper, Nepal Samachar Patra on 25th January 2020, 47 households of very poor and backward communities located in Chhelurng, ward no. 13, Tansen Municipality, Nepal, have installed solar PV systems with financial support from Tansen Municipality.[26] Those households were spending night in dark for many years. In the past, they used the kerosene lamp with very poor illumination and also deteriorated their health from smoke coming from burning of kerosene.

Now with solar PV systems as shown in Figure 5, people are very happy with better lighting in inside and outside houses. The Figure 5 shows that installed solar PV system in one of the houses. As shown in

Figure 5. Solar PV systems installed in Chhelurng, ward no. 13, Tansen Municipality, Nepal

figure, two solar PV systems have been installed as two families are living in the same house, which is normal in rural areas of Nepal as brothers of the same family are separated and lived in the same house. According to news, in addition to the lighting, they have facilities of mobile charging, increased access to radio and TV, study to children, saving of money from purchasing of kerosene and easiness of daily households work. People have further said that solar PV systems have illuminated the whole village and facilitated for organizing marriage, and other rituals and cultural activities of the communities. They claimed that they are free from smoke, and light from solar PV system is far better than kerosene lamp.

The lessons learned from off-grid solar PV for rural electrification in rural areas of Nepal can be very useful for designing the similar programme in developing countries. The following are the key lessons learned.

- Demand based dissemination approach increases the sense of ownership, acceptability and use of technology.
- Mix of policies such as subsidy, tax exemption (import tax and value added tax) will increase the affordability of technology by lowering the initial cost.
- Appropriate financing model with mix of subsidy and credit reduces the chance of misuse of the subsidy and risk.
- Proper institutional arrangement and appropriate policy enablers are necessary for successful implementation.
- Subsidy promotes the technology initially for market penetration, but credit is necessary for market expansion.
- Quality assurance of solar PV systems increase the adaptability and reduce the risk of financing through financial institutions.
- Proper system sizing and technical designing are necessary for efficient use of solar PV electricity.
- Mandatory provision of after-sales service, and repair and maintenance ensure the functionality and reliability of the installed systems.
- Reward and penalty system increase the fair

competition among the installer companies.

- Users training for operation and maintenance of solar PV systems is effective for continuous operation of the systems and their sustainability.
- Continuous training and capacity building can play a key role for ensuring effective monitoring and maintenance of installed systems.
- Robust monitoring and quality control mechanism support for taking the corrective measures in time.
- Coordination and collaboration among the key stakeholders (Government, donors, private sector, NGOs, etc.) are necessary to avoid the duplication and proper use of resources.
- Despite the success of the solar PV programme due to number of innovative factors, dissemination is suffering from uncertainty in political conditions with politicians and governments often decide in an ad-hoc basis to expand the national grid to rural areas even though it is too expensive and not feasible. For example, some rural households have cases of abandoning the use of already installed solar PV systems after reaching the national grid to their areas with political reasons. This is misuse of subsidy which could be used in other un-electrified areas.

Conclusions and Recommendations

The success of dissemination of solar PV technologies for rural electrification in Nepal demonstrate that access to financing (both subsidy and credit), enforcement of effective quality control and after-sale service, customer focused market development, active involvement of key stakeholders, robust monitoring and quality assurance, and collaboration among the key stakeholders contributed for scaling-up. Furthermore, the financial innovation and private sector involvement are two main factors for higher penetration of decentralized solar PV technology to enhance electricity access in rural areas of Nepal. However, the subsidy alone is not enough to the low income households to install the solar PV at least for meeting their basic electricity need.

There is need for providing easy access to credit with low or zero interest to cover poor households as well as wider coverage in the rural areas. It is observed that subsidy is not good for market development of solar PV technology for long-term, rather there should be flexible financial instruments such as collateral free credit or solar PV system itself as collateral, output based aid, vendor financing for both users and supplier or installer companies, and risk mitigation measures for rural financing sector in ensuring the dissemination of solar PV technology as well as their sustainability. The off-grid solar projects are generally in smaller capacity, so bundling smaller projects for concentrating energy loads in particular area can support to increase the market size, which will ensure the economies of scale. There might be less credit risk to banks and can minimize the transaction costs as well as low cost to companies for providing after-sales service and maintenance.

There is also need for developing technical capacity and infrastructure for distribution, installation and providing adequate after-sales service at the local level together with strict adherence to quality standards, quality control and assurance of solar PV systems. In addition to these, regular technical feedbacks on performance of the compo-

nents is very important to customize best suited components for rural areas. Furthermore, there is need for reduction of cost of solar PV systems through use of latest technology such as LED lamps (high efficient lamp) which not only reduce the cost but also reduce the size of the solar PV panel and battery. The private companies responsible for manufacturing, supply, installation and providing the after-sales service need to remove the barriers to demand, supply and scalability and adapt the standard process and guidelines. Ultimately, the combination of technology, financing and institutional aspects can be strengthened to accelerate the rural electrification through off-grid solar PV technology and enhance the energy security in rural areas of Nepal.

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