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Japan International Cooperation Agency

Dissemination of Renewable Energy into Rural Communities

Study on photovoltaic and small-hydro projects in East Africa

Summary Report

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1. Background

Home lighting is considered a basic human need. It significantly improves the quality of people's life. However, most people living in rural areas of developing countries have no access to electricity, and need to spend a substantial part of their income to buy kerosene for lighting, which may be hazardous to their health because of fumes. In contrast, those who live in urban areas of developing countries can get higher income and benefit from safe and clean electricity supply. As a result, the gap between rural areas and urban areas is widening, which will lead to social unrest. Therefore, rural electrification is a priority topic in the political agenda of many developing countries.

Rural communities of developing countries are often rich in renewable energy resources such as solar, hydro or wind power. Given the growing concern over global warming, the importance of rural electrification by renewable energy has been emphasized recently. It has become a very urgent and important issue now. It is strongly expected that industrialized countries help developing countries promote rural electrification by renewable energy. Japan's role in this topic is becoming more and more important, because Japan has a lot of experience in renewable energy development. Using such knowledge and experience, Japan International Cooperation Agency (JICA) has been implementing many rural electrification projects.

Recently, JICA places an emphasis on aid for Africa. In East Africa, JICA is promoting rice farming in Uganda and established an initiative named "Coalition for African Rice Development (CARD)". JICA is now willing to promote rural electrification by local renewable energy as an integrated project with CARD to aim for comprehensive development of rural communities and income generation of farmers.

Rural communities are often endowed with sufficient sunlight, which can be converted easily into electricity. Solar electric power, or photovoltaic (PV) power, is generated on site without using fuel or extending the electricity grid, which makes it the cheapest and easiest solution for providing basic electricity supply in remote villages. PV technology used in remote villages is simple and easy. However, PV systems introduced in Africa so far are limited. We need to find solutions on how to accelerate PV dissemination in Africa.

On the other hand, in some countries where hydropower resources are abundant, small hydropower can also play an important role in rural electrification and community development. A comprehensive community development project that can supply electric power for both households and rural enterprises is possible with small hydropower. The development of small hydropower always needs custom design, which requires a wide range of technical expertise, is more complicated and difficult than PV projects. Hence, there are few examples of small hydropower development projects in Africa due to lack of expertise. However, there are a lot of small hydropower potentials in East Africa including Uganda. It is also an urgent need to develop a scenario on how to develop small hydropower for rural electrification and community development.

This study was conducted to examine the current status and future prospects of photovoltaic (PV) and small-hydropower utilization in East Africa, rural Uganda in particular, from various viewpoints, and intended to propose a sustainable development model of PV and small hydropower applications in rural communities.

2. Rural Electrification in Uganda

In 1999, the rural electrification rate of Uganda was estimated only 1%. There was a concern that the gap between rural villages and urban areas was widening and would cause serious social unrest in the country. The Government of Uganda (GOU), therefore, revised the Electricity Act in 1999 and redefined its rural electrification strategy. The new policy is to accelerate rural electrification by private sector's initiative, and the GOU will support rural electrification projects by providing subsidies. Before that the Uganda Electricity Board (UEB) was responsible for electrification, but in rural areas UEB was not active to implement electrification projects.

The GOU developed Rural Electrification Strategy and Plan (RESP) in 2001, in which the goal of rural electrification by the year 2010 was set 10%[1]. This meant that additional 400,000 households in rural areas were to get access to electricity in ten years. The Rural Electrification Agency (REA), established by the new Electricity Act in 2003, has been promoting rural electrification projects under the framework of RESP using the Rural Electrification Fund (REF).

Goal of rural electrification (RESP 2001)

	2000	2005	2010
Rural population	18.6 m	20.2 m	22.0 m
No. of rural households	3.8 m	4.1 m	4.5 m
No. of electrified rural households	80,000	164,000	450,000
Rural electrification rate (%)	2.1	4	10

Under the new rural electrification policy, there are three types of projects pursued: 1) grid extension, 2) mini (isolated) grid development, and 3) off-grid or PV development. All these projects are supposed to be developed by private initiatives. The World Bank with GEF has been executing the Energy for Rural Transformation (ERT) program since 2002 to help GOU achieve the goal of 10% rural electrification.

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1 The target year is now extended to 2012.

Now, the Indicative Rural Electrification Master Plan (IREMP) that aims to present concrete rural electrification project lists is being drafted with the assistance from the ERT program. In this master plan, various rural electrification methods are evaluated taking development costs and local conditions such as population and distance from the grid into account. It is concluded that off-grid systems such as PV or small hydropower are more costly than grid extension in relatively populated areas where the priority of electrification is high. Therefore, not many off-grid projects are planned for the near future under IREMP. However, off-grid system is still viewed as a viable option for remote areas where houses are dispersed and the national grid will not come in the foreseeable future.

3. Energy Needs and Renewable Energy Use in Rural Uganda

This section presents the results of a field survey conducted in this study in rural isolated villages in the Central, Western and Eastern regions of Uganda. The purpose of the survey was to learn the current energy needs in remote villages and renewable energy use, if any, to find out prospective renewable energy applications that will contribute to poverty reduction and community development. The survey covered energy use at individual households, social and public facilities such as schools and health centers, and rural enterprises that include agro industries, retail shops, entertainment halls, and battery charging business.

Rural households still predominantly use traditional energy sources in both electrified and un-electrified areas. Firewood and charcoal for heating and cooking, paraffin and kerosene for lighting and dry cells for radios are the common energy sources. Knowledge about alternative energy is limited. During the field survey, some well-off families were found spending a lot of money on kerosene for lighting with no idea of alternatives like solar lantern, for example. According to monitoring and evaluation reports of the ERT program of the World Bank, firewood, charcoal and paraffin are still ranked high and preferred by rural people primarily because of their cost and availability, even in the areas where they have access to grid electricity. However, the fact that people go to towns to charge their mobile phones shows that they spend time and money once they are convinced of benefits from modern energy or electricity. This is a good suggestion that there are ample opportunities for the introduction and dissemination of renewable energy in rural communities.

It is clear that PV system can supply limited capacity of power and, hence, its application for productive use is very difficult. It is suitable for lighting and small-scale electricity applications. On the other hand, electricity from small hydropower can be used in the same way as grid electricity.

3-1. **Major findings**

a. Advantage of PV lighting is not widely known

Awareness about solar energy is low among rural people, and they have a fairly limited and narrow view that PV system is expensive but requires little maintenance. On the other hand, main players in the energy sector such as policy makers, service providers, dealers and PV system owners, who have a good understanding of PV technology, clearly recognize its comparative advantages over other energy options. They will use PV systems for lighting and battery charging, especially for charging mobile phones, and also for radios, TVs and PCs. In Uganda where the grid power supply is unstable and electricity tariff is high, PV system is appreciated even in the electrified areas as a back-up power supply in case of load shedding and blackout.

Size of installed Solar Home System (SHS) varies a lot. Household systems range in size from 20W to 50W, and in price from $500 to above $1,000. Main customers are wealthy individuals and shop owners. They use PV systems primarily for lighting. On the other hand, institutional systems for schools, health centers and administrative offices are larger in size and more costly. Other than lighting, hospitals and health centers use PV for drug storage and vaccine refrigeration, and administrative offices and schools use it for PCs and audio visual equipment like TVs.

As for battery charging, PV is effectively used for mobile phone charging in remote villages to meet the strong need of mobile phone users. PV charging shops, large or small, are often found in remote villages and attract many users every day. The idea of mobile phone charging by PV is spreading very fast in rural areas. In contrast, there are few people who use car batteries at home in rural Uganda. One reason is that car batteries are expensive, about $100, and also the idea of using car batteries for home lighting and other purposes is not widely known and difficult for many people to understand.

b. Bright and safe PV lighting improves living conditions and provides security.

Once PV system is installed, quality lighting is greatly enjoyed and appreciated at rural households, rural enterprises and social facilities such as health centers and schools. It provides much brighter and more stable lighting than kerosene or paraffin lamps, and protects people from diseases such as asthma, cough and eye problems caused by fumes. PV lighting also prevents accidental fires. The price of kerosene and paraffin is increasing, so that fuel cost saving is also big. It is found that PV lighting at shops attracts more customers at night and contributes to sales increase. Owing to PV lighting, more emergency cases are accepted by health centers during nighttime. At schools, large-scale SHS is installed to supply power to operate computers and other office machines in addition to lighting. Some farmers show interest in using PV pumps for irrigation.

c. Village people without electricity go long distance to charge their mobile phones.

Telecommunication through mobile phones and Village Phones (pay-phone business) is spreading rapidly in rural Uganda recently and changing people's life. Shop owners in small village centers have either mobile phones or easy access to Village Phones to talk with their clients, suppliers and business fellows. Farmers make calls to negotiate with middle men/women to sell their products for good prices. Family members living in towns give mobile phones to their parents and relatives in remote villages to make sure that they can communicate any time. Rural residents make calls to get urgent transportation and make appointments. People also use mobile phones to send and receive money. As a convenient and useful tool, mobile phone is becoming a necessary part of rural life, which inevitably creates demand for electricity. Since many mobile phone users don't have access to grid electricity, they spend a lot of time and money for charging their mobile phones. They go to towns for charging, or ask their children to take mobile phones to nearby charging centers on their way to school in the morning and ask somebody to come back with their mobile phones in the afternoon.

MTN-Uganda started Village Phone business in 2003 by training operators who live in un-electrified areas. According to the Village Phone manager of MTN-Uganda, the total number of owners/operators of Village Phone in Uganda was about 30,000 in mid 2008 with some 87% increase from last year! Among them, 85% were rural house wives. The manager explained that the average income of operators amounting to 20,000Ush

($12) per month, which was making a big change in their life. Some operators could pay school fees for their children, others got three meals instead of one per day, or repaired their houses. PV technology and battery charging supported the success of Village Phone business.

d. PV system is sometimes not well utilized or maintained.

Lack of electricity in health centers is a major problem in providing services such as improved sterilization, treatment of night patients, vaccine preservation, laboratory investigations, use of computers, communication for information sharing, consultation and referring and so forth. In terms of information and communication, it is considered essential for major health centers to develop ICT infrastructure including telephones and information/data management systems with PV system as a source of electricity supply.

However, all four health centers with PV systems that the study team visited had no information and communication tools. The PV systems were designed for lighting purpose only. Also, the staffs were not informed of PV technology and its application and maintenance. They had no idea how to use the PV system for charging their mobile phones, for example. In order to make the best use of PV systems, as the ERT report pointed out, appropriate staff training and sufficient funding for operational expenditure need to be in place.

3-2. **Prospective renewable energy use for poverty reduction and rural development**

Based on the field survey, it can be concluded that renewable energy, PV or small hydro, can effectively improve rural people's life and contribute to community development. The expected areas of renewable energy application are shown below.

A. For improving living conditions, income generation, and social welfare

- Household: Lighting for households, and street lighting for security;
- Educational institutions: Lighting for class rooms and accommodation, use of audio

visual equipment like TVs & CD/DVDs and ICT equipment including computers and copy machines, and back-ups for load shedding.;
- Health service institutions: Lighting for service facilities and staff accommodation, PV refrigerator for drugs and vaccine storage, and back-ups for load shedding.

B. For developing rural enterprises:
- Agro industry: Thresher and milling machine run by small hydropower;
- Night lighting: Lighting for shops and offices
- Battery charging: Mobile phone/battery charging
- Entertainment: Audio visual equipment at entertainment halls and cafes;

C. For improving rural infrastructure of ICT
- Mobile phone charging:
- Car battery charging: For household electricity supply for radios, TVs , etc.
- Access to information: Tele-centers, Internet cafes, and Entertainment halls etc.;

4. Photovoltaic System

It is estimated that about 1.6 billion people live without benefits of electricity. Now, the international society is striving to reduce poverty in developing countries, and rural electrification has become one of the priority issues to realize the objective. Also, the global climate change is becoming a big concern of the world. To mitigate the problem, we all must reduce greenhouse gas emissions. To promote renewable energy and to reduce fossil fuel consumption is strongly needed not only in industrialized nations but also in developing countries.

In order to promote rural electrification, PV technology is considered appropriate for isolated and dispersed requirements in rural Uganda. It is one of the most promising power sources for small-scale lighting applications off the grid. PV systems require no fuel supply and have no moving parts. Therefore, their operation is generally reliable and maintenance is easy compared with other stand-alone power supply systems such as diesel generators. Once installed, they can work for a long time with little running cost, which is a big advantage in remote areas.

However, PV technology has a major disadvantage of limited capacity for requirements beyond household. PV can supply small power for lighting, mobile phone charging, radio and television, but cannot be applied for agro processing such as de-husking or milling, and other productive uses such as lumber processing or welding. For these applications, diesel generators or hydropower generators are required. In limited cases, there is some possibility of using PV for small-scale pumps up to around 2kW. People's expectation for PV is high, but its actual dissemination into rural communities is slow mainly due to high upfront cost and lack of knowledge.

4-1. Solar Home System and Battery Charging Station

Solar Home System (SHS) is a popular type of PV application to electrify small rural homes. A typical SHS is a 12-volt (12V) direct-current (DC) stand-alone system. It consists of a solar panel, charge controller, battery and other miscellaneous parts such as brackets, cables and switches. Battery Charging Station (BCS) is another type of solar power system. With BCS, users must transport their batteries for charging, which is not convenient. BCS, therefore, is regarded less advanced than SHS.

Comparison of SHS and BCS

	SHS	BCS
Solar Panel		
Charge controller		
Battery		
Operation and maintenance	・Automatic battery charging ・Switch on-off only ・ Battery life is long due to re-charging everyday	・Transport battery for charging ・To be operated as business ・Risk of short battery life because of over-discharge
Cost	・User owns SHS ・Price ranges from $500 to $1000 ・Consumer loan is common	・ BCS is usually built as a public or commercial facility ・User pays charging fees

4-2. Rural Electrification by Photovoltaic Technology

In 1998, UNDP/GEF started the first PV rural electrification project in Uganda; Uganda Photovoltaic Pilot Project for Rural Electrification (UPPPRE), which focused on the linkage between PV dealers and local micro lenders. It laid the foundations for PV market development. After UPPPRE, the World Bank's ERT program followed. Under the ERT program, a choice was made to use a competitive market development business approach as opposed to a regulated concessions approach. The market competition model was chosen for a number of reasons, such as consistency with the GOU's strategy of paradigm shift from electrification as a public service to demand driven private sector initiative. The ERT program has a sales-based grant system to PV dealers to increase SHS sales in remote areas. The GOU set the goal of 80,000 PV units in the Rural Electrification Strategic Plan (RESP), but it is estimated that only 10,000 units have been installed mainly by wealthy households, retail shops, public institutions and NGOs.

The nature of PV implementation in rural communities is straightforward. PV suppliers select appropriate components and assemble them for installation at site. It requires no high-level technical expertise. In other words, PV suppliers just sell appropriate size of SHSs to the order of customers. Hence, how to sell many PV systems to potential users is a fundamental issue to be resolved, and therefore, "delivery model" and "consumer financing" have been major issues in aid projects. There is no proven success model of PV rural electrification, which makes it really challenging for aid workers.

4-3. Assessment of PV application in Uganda/ Barriers of PV dissemination

So far the results of SHS installation have been far less than the target. There are not many examples of average income households installed SHSs. Most village farmers in rural Uganda cannot afford SHS even though some subsidy program and consumer financing program are implemented. It is recognized that the following barriers hinder the growth of PV market in Uganda.

a) High prices of SHS

A typical 50W SHS is sold for about $1,000 in Uganda, which is very high compared with similar size models available in Asian countries. High SHS prices can be explained by two factors; solar panel price and procurement in small volume. Firstly, the high price of solar panels in the world market is a big problem, which was not expected ten years ago. In particular, the demand for solar panels is rapidly increasing in Europe, which is pushing up the panel price. Now, developing countries need to compete with industrialized countries to secure solar panels. As a result, the panel price, which accounts for the largest part of SHS price, remains high. Secondly, the current practice of procurement in small volume results in high unit cost. PV suppliers import PV equipment in a small lot and therefore they cannot negotiate price discount.

b) Lack of knowledge base among villagers

There is almost no information available about PV and only few examples of SHS are found in remote villages. Local people have no opportunities to learn about PV, and hence, there is no knowledge base created on PV in rural communities. So far, there has been wide spread perception that raising awareness among potential users is important to increase sales of SHS. Thus, efforts are made to provide information on PV to potential users to raise their awareness. The fundamental question is whether awareness of PV is enough to motivate rural villagers to buy SHS. This is a very important issue. Maybe, simple awareness is not enough for them to make a decision to pay for SHS.

c) Insufficient information transfer on SHS maintenance

To achieve the sustainability of SHS, it is important to provide necessary information to SHS users for maintenance and troubleshooting. If SHS users are located near urban areas, PV technicians can visit their customers, check the conditions of SHSs. But in reality, SHSs are usually installed in remote villages, and the cost of visiting the villages is high, which SHS users cannot bear. If SHS users fail to maintain their systems, they spread negative views about SHS in village, and the process of SHS dissemination stops. The key issue is how SHS users are instructed properly until they master necessary skills and become confident about maintenance. In particular, having a clear understanding on battery maintenance is the most important issue.

5. Model Plan for PV Dissemination

5-1. Mechanism of SHS introduction

Why is the dissemination of PV systems so slow in remote communities in Africa? Of course, the high upfront cost of SHS is a big problem. Up to now, there have been many projects conducted to promote rural electrification by PV. The main objective of those projects is how to sell more SHS to rural people by developing the market and its players. Almost always those projects are designed to improve conditions on the supply side. PV suppliers and financial institutions that are the major players in the PV market are focused. In contrast, consumer education about SHS has not been prioritized. In most cases, it was conducted briefly and poorly, so the SHS users were never able to fully understand what to do for the operation and maintenance of their SHS. Project activities are biased to the supply side, rather than to the demand side. The underlying idea is that rural people can understand the benefits of SHS easily and try to buy if good sales mechanism, product suppliers and money lenders, is available. Many ideas, subsidies and consumer loans for example, have been tested to improve the affordability of PV systems. However, dissemination of SHS into rural communities in Uganda has been limited so far. Are there any other conditions effective for facilitating the sales of SHS?

When an initial SHS is installed in remote village, the villagers who have had no chance of learning about PV technology will just watch it from the sideline. They will never try to buy SHS simply because they do not know clearly what SHS is for. At this stage, they can watch SHS and get AWARE of PV technology and SHS to some extent, but they are NOT CONFIDENT enough to consider purchasing SHS. When they talk with their relatives or friends about PV later, they can get more information and accumulate knowledge about it. Step by step, they become confident about PV. Thus, it would make problems clear if the concept of “confidence” is distinguished from “awareness”.

If the first SHS user in village has some problems with his SHS, he will criticize it and spread negative information in the village. The villagers, then, will lose interest and not consider buying SHS anymore. On the other hand, if the first SHS user can use and maintain the PV system successfully for a long time and get benefits worth for his expenditure, a good reputation about PV will spread in village and the villagers get interested in learning more about PV. If good SHS user training is provided, they can use SHS for a long time and feel satisfied with it. Then, they will become strong supporters of SHS and publicly endorse it on many occasions.

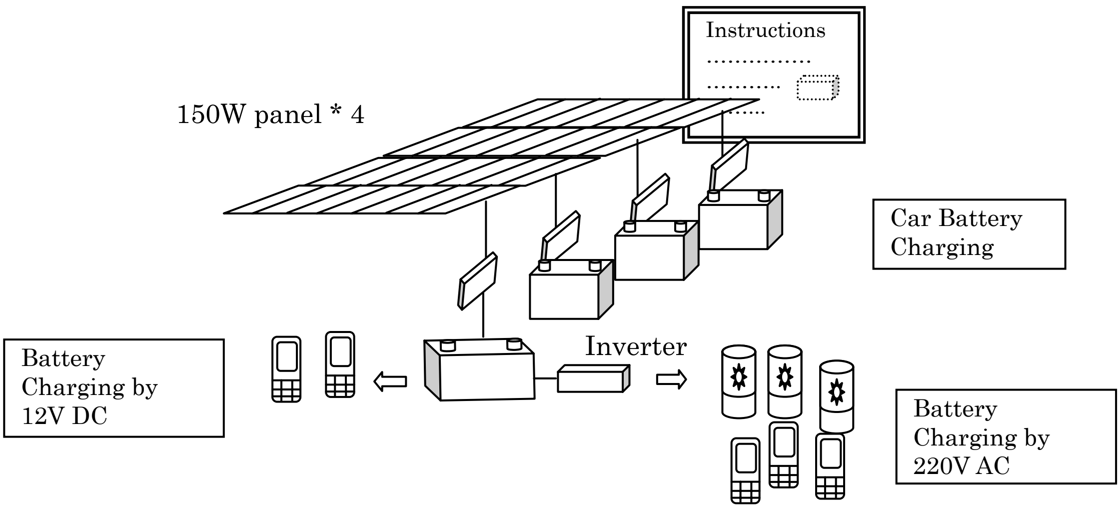
To make a decision to buy an expensive item like SHS is not easy. New SHS buyers want to collect information as much as possible beforehand and also try to use it to make sure that SHS really provides the benefits as explained. In summary, in order to increase sales of SHS in remote areas, there are two prerequisites; confidence in SHS and good mechanism for user training.

Suppose a situation, in which many people in remote un-electrified villages know well about PV and SHS. When an initial SHS is introduced, they can understand its functions and benefits easily. Some people will consider buying SHS when the initial SHS is confirmed working well. Also, since they already have knowledge about PV technology, they can use and maintain SHS without difficulty. They can quickly master necessary skill for operation and maintenance of SHS. They will get satisfied with their SHS and recommend it to their friends. Thus, with the knowledge base about PV, a mechanism of sustainable operation of SHS will be created, which accelerates its sales expansion.

5-2. **Development of Community Battery Charging Station (First Stage)**

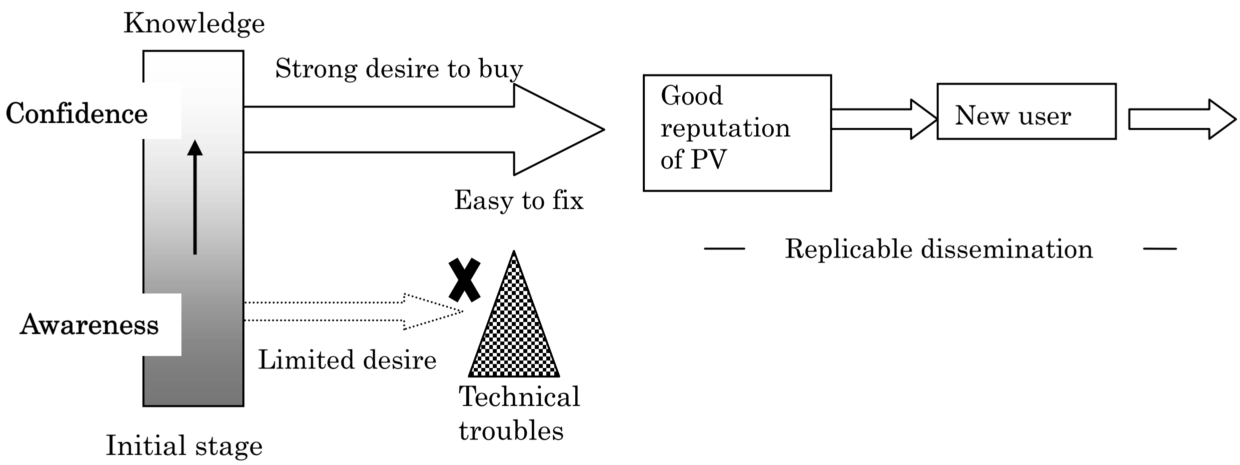
It can be said that creating confidence, not awareness, about PV among villagers is the key to accelerated expansion of SHS in rural communities. Then, concrete plans to develop villagers' confidence about PV need to be worked out. The best method is to provide a hands-on learning opportunity to the villagers. One idea is to provide or lend mini-scale SHSs, or solar lanterns, to some villagers. Solar lantern is affordable small-size lighting equipment with PV technology. It has a small solar panel, battery and lamp. However, those who received solar lanterns will keep them at home and other people may not be able to get a chance to watch and learn about PV. Also, solar lantern is so small that its functions are limited; for example, it cannot charge car batteries. Thus, the knowledge creation effect would be limited.

A recommendable idea is to set up PV-based Battery Charging Stations (BCSs) in remote off-grid communities and make the stations open to the public. The "Community BCS" should be designed to provide charging services for mobile phones, lanterns and car batteries. Anybody who wants to use the BCS can use it for a small amount of fee. At present, there are many villagers who are charging their mobile phones outside their community. If a Community BCS is built in their village, many users will come for charging their mobile phones and car batteries to save time and money. Furthermore, mobile phone users will increase because charging becomes much easier. They gradually learn about PV and acquire knowledge and skill to use PV equipment. Even non-users can watch the process of charging and get interested in PV. With such a mechanism, the knowledge base about PV will be developed in the community, which will underpin the dissemination of personal PV systems, solar lanterns and SHSs, and their sustainable operations. Thus, the BCS works as a tangible learning tool that creates knowledge base on PV in the community.



A concept of Community BCS

Using the Community BCS, rural villagers can acquire knowledge about PV technology and eventually get confidence in PV, which is a starting point of replicable dissemination of PV systems. With such a strong motive for PV among potential users, efforts of PV market development will work well. Confidence development should come first before market development. Some villagers who have confidence in PV technology will seriously consider purchasing solar lanterns and SHSs. Also, with the knowledge base they can easily deal with technical problems of PV systems and improve their sustainability. Thus, once the community has created a strong knowledge base on PV, PV systems will become sustainable and will be highly appreciated by the village people. Under this situation, new PV users will continue to come out, which leads to replicable dissemination of SHS. See the illustrated mechanism below.

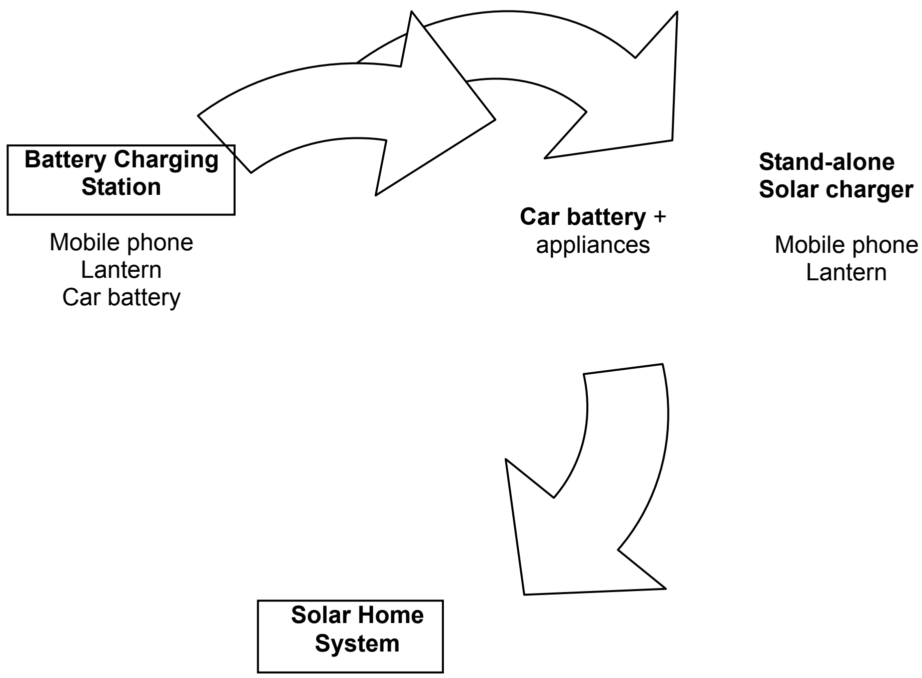


Mechanism of knowledge accumulation and PV dissemination

The idea of Community BCS is similar to that of Energy Kiosk developed by UNIDO in Kenya. The Energy Kiosks will provide energy services to remote/off-grid communities, far from existing energy sources, and target those who are too poor to pay for the initial investment for energy related installation and those whose energy needs require a large amount of time and labor in order to get their needs satisfied. The system will be run and operated by the rural community.

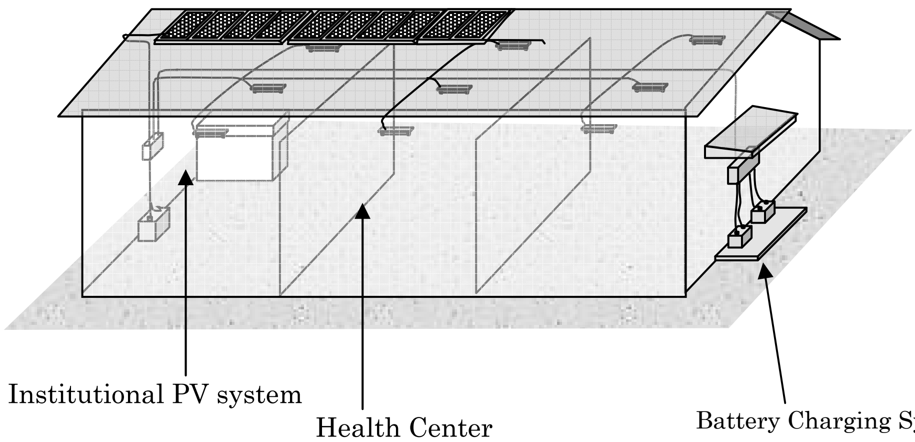
An Energy Kiosk is a shop, where one can buy electricity in the off-grid villages of Kenya, and it may be for battery recharging for the newly introduced LED lamps, mobile phones, or automobiles, or for running tiny or small industries, agro or food processing appliances, or micro or small enterprises, or to run community centres, or to power nearby local schools by extending lines from the Kiosk, or any other small power applications. The Kiosk receives electricity from a local renewable energy source such as a micro hydro power unit, solar, wind or biomass based power generator or a DG set running on locally available vegetable oils. (UNIDO website)

In summary, the recommended model plan is to develop Community BCS to provide rural villagers with chances to learn about PV by using it, which leads to the creation of knowledge base on PV in the community. Then, the villagers will become confident about PV and try to buy personal PV systems. At this stage, PV delivery model/financing scheme development will work well. The ultimate goal is to introduce SHS to average households. This is a time communing process, but necessary steps to achieve community wide dissemination of PV systems.



Stages of PV dissemination in rural community

The Community BCS can be combined with institutional PV system at public facilities such as schools or health centers. Institutional PV systems are usually designed to have more capacity than expected power requirements, and actual power usage is usually below the capacity. Therefore, the underutilized part of institutional system can be used for other applications like mobile phone charging with small modifications. However, more PV panels are necessary when the need for car battery charging is strong. In that case, some solar panels should be added to provide car battery charging service. If the BCS is combined with institutional PV system, the total investment cost can be reduced and also, the management of BCS will become easier if the public facility helps the daily operation of BCS. Furthermore, the facility can get charging fees from users, which can be used to cover a part of operation expenses. With the income, the maintenance cost of the combined system can be secured easily. However the staffs of the facility are not used to manage the BCS and deal with users. A good management model must be developed.



Combination of Community BCS and Institutional PV system

5-3. Promotion of Solar Lanterns and Cost Reduction of SHS (Second Stage)

After the knowledge base is created by the Community BCS, some people who have confidence in PV will try to use solar lanterns and SHSs. Solar lanterns are new products and will be marketed as an entry product of PV. Many people can afford solar lanterns because the retail price is around $50, which is the same price range of mobile phones. Thus, the market development for solar lanterns will be the most likely scenario. In this case, it might be necessary to implement certification and inspection of solar lanterns in the market and some testing equipment needs to be provided.

Compared with solar lanterns, SHS is still expensive and its price should be reduced significantly. At present, the average price of SHS in Ugandan market is around $20/W. The target of price reduction should be in the range of $10~$11/W. Some ideas of SHS price reduction are given as follows:

1) Provision of solar panels by "Non-project grant scheme"
2) Long-term loan to GOU for purchasing solar panels in a large volume to reduce their unit price
3) Importing used solar panels from Japan

Target SHS Price

	Cost per W
Solar Panel	$5~6
Charge controller	$1.5~2
Battery	$3~4
Cables	$0.5
Frame, installation	$1
Total	$11~

6. Small-Scale Hydropower

6-1. Hydropower in Developing Countries

Hydropower development is a project to design and construct a power generation and transmission scheme based on the water flow and geographical conditions of selected site. It is a tailor-made type project, which requires a thorough understating of the diverse technical, environmental and planning aspects that lead to a successful hydropower scheme. The necessary steps typically include site survey, planning and design, equipment manufacturing, civil engineering/construction, and operation of power plant. Therefore, it is necessary to develop a different approach from photovoltaic (PV) power development, which is based on the dissemination of mass-produced PV systems by the market mechanism. One favorable consequence of hydropower development is contribution to enhancement of domestic technical capability.

Hydropower development in Uganda is viewed as a very important investment issue for the economic development of Uganda, because it will provide electric power that is necessary for the socio-economic development of Uganda where the electrification rate is still low and development of domestic industries lies ahead. It will also contribute to acquisition of foreign currency through exporting electricity to neighboring countries in future.

There is an increasing need in many developing countries for power supplies in rural areas, and hydropower, if available, is an ideal power source in mountainous areas where grid extension is very difficult. With hydropower technology, local renewable hydro energy resource is transformed to electricity that is supplied to households and rural enterprises. Furthermore, it is environmentally benign because it does not consume fossil fuel for power generation. However, there are some difficulties in hydropower development projects; remoteness of construction site and heavy construction work in mountainous area, for example. As a result, it often happens that development cost becomes higher and construction period becomes longer.

Hydropower schemes are generally classified into the following categories based on the size of power plant. In this study, off-grid small-scale hydropower is focused.

Large Scale Hydropower	――――――――――――	100MW~
Medium Scale Hydropower	――――――――――――	10MW~100MW
Small Scale Hydropower[2]	――――――――――――	1MW~10MW
Mini Hydro	……………	100kW~1MW
Micro Hydro	……………	~ 100kW
Pico Hydro	……………	~ Several kW

Technologies applied for small hydro power are fundamentally the same as those for conventional large-scale hydropower. A wide range of expertise in civil engineering, power generation and transmission/distribution system, from planning to construction, are required. Key technical areas are hydrology, hydraulics, structural engineering, hydro-mechanics, electrical engineering, and electronics. Facilities and equipment for hydropower vary from civil facilities, power generation equipment, transmission/distribution facilities to electronic controlling system.

6-2. **Off-grid Small Hydropower**

There are two types of hydropower schemes: one is grid-connected scheme and the other is isolated off-grid scheme. In developing countries, hydropower is usually planned and developed to increase power supply capacity to meet the growing electricity demand. Those hydropower schemes are almost always planned to supply grid electricity and usually given high priority in economic development plan. Hydropower development projects under the scenario usually require a long preparation period and are developed when they become feasible from technical, financial and environmental viewpoints.

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2 In Uganda, hydro smaller than 20MW is defined as small hydro.

On the other hand, there is a strong need to develop off-grid small hydro from the viewpoint of rural community development. Off-grid hydropower schemes are planned for rural power supply. The development of off-grid small hydropower is often more demanding and complicated than grid-connected scheme. For example, it is mandatory for off-grid hydro to secure enough water flow even during the dry season to supply power to meet the electricity demand. This requirement is irrelevant in case of grid-connected hydro. Furthermore, the operation and maintenance of off-grid hydro is critically important. To operate the rural off-grid hydro efficiently and continuously as a small business is a big challenge. Thus, there are a lot of extra activities required other than power plant development such as electricity tariff setting, power supply contract, operator training, accounting, etc. As a result, off-grid micro hydro development requires a broad range of skills and expertise in engineering and socio-economic activities. These non-technical requirements of off-grid hydro often discourage private investors. In order to develop off-grid hydro, therefore, strong support from the government is always necessary to compensate those difficulties. It is necessary to develop a different approach to promote such projects that are not attractive to private investors. Because of its smaller project size, off-grid hydropower development may use off-the-shelf components or locally made machinery. This kind of approach is known as the localized approach. Off-grid small hydro is perhaps the most mature of the modern small-scale decentralized energy supply technologies used in developing countries.

An off-grid small hydro can provide enough power even for industrial applications, which is not possible by limited power supply from PV system. Therefore, off-grid small-scale hydropower in remote area is developed to provide power for rural enterprises as well as households in the rural community. The household electricity demand includes lighting, charging batteries and small appliances. The commercial and industrial use of electricity varies from agro processing, water pumping to manufacturing tools. Thus, off-grid small hydropower is viewed suitable for community development that includes rural enterprise development in un-electrified rural areas. In remote areas, it is difficult to extend the electricity grid in the foreseeable future. Therefore, off-grid small hydro development is strongly expected. If an off-grid small hydro development project is formulated involving the government, donors, local enterprises and community people, it will be an excellent development project. Moreover, this type of development methodology would be acceptable for donors as a model project for community development to apply local hydropower resources, to improve the ratio of electrification and to promote local industries.

Although the construction work of off-grid small hydropower is generally simple and small in scale, the planning and design of each component requires deep understanding of broad technologies relating to hydropower. Therefore, developing countries like Uganda cannot develop off-grid hydro easily due to extreme shortage of experts on hydropower development. Almost always donors must be involved from the planning stage in case of off-grid small hydro development, which is a bottleneck in promoting rural electrification by small hydro. Compared with PV system dissemination, the nature of off-grid small hydro is different. PV systems, which can be standardized, are to be promoted based on the market mechanism. No much expertise are required for PV business.

As it was mentioned earlier, private investment in off-grid small hydropower development projects is very unlikely. Therefore, the assistance from the national/local government is essential. The GOU may consider the following points as prerequisites for off-grid small hydro development.

1) Priority for the electrification of target community,
2) Available power and power demand,
3) Financial advantage over alternatives such as diesel power generation, and
4) Other benefits derived from hydropower development

6-3. Issues in Off-grid Small Hydropower Development

6-3-1. Small Hydropower Potential in Uganda

Judging from geography and precipitation, small hydro power potential in Uganda is rich along the western to southwestern border areas and in the eastern mountainous area.

6-3-2. **Administrative Capacity for Promoting Small Hydropower**

There are very few officials in GOU who have work experience in hydropower development. This is attributed to the fact that there have been very few hydropower projects conducted in Uganda; three large-scale projects so far and several small projects. The shortage of government staff on hydropower causes delay in the process of project proposal evaluation, project formation and arranging financing deals. The driving force of hydropower on the government side is weak. Human resource development in related public organizations is essential to the smooth implementation of programmatic hydropower development in Uganda.

6-3-3. **Private Sector Capacity for Promoting Small Hydropower**

The private sector of Uganda is expected to play a key role in developing off-grid small hydropower, from project planning, community mobilization, equipment design and manufacturing, and construction work, etc. However, there are very few private companies and engineers having experience in hydropower projects. The reason is the limited number of projects and infant hydropower related business in Uganda. This situation obviously delays hydropower project formation and its facilitation. If Uganda can take an initiative in planning, designing and manufacturing activities of small hydropower, it will definitely accelerate its development. At the moment, Uganda needs to rely on donors and foreign companies entirely to implement a new small hydropower project.

6-3-4. **Financial Arrangement**

Hydropower development is generally a capital-intensive venture. Small hydropower is not an exception. In case of grid-connected hydropower that aims at selling electricity through the grid, the developer or investor is responsible for securing funds for the development. On the other hand, in case of off-grid small hydropower that aims at community development by electrification, the beneficiary is the people and rural enterprises in the community. Therefore, in principle, the community should bear the development cost. However, it is usually difficult for the community to bear the whole development cost, and the substantial part of the cost needs to subsidized by GOU (or Rural Electrification Fund) and donors. Furthermore, in addition to the capital investment, it is necessary to secure enough income to cover the operation and management cost in case of off-grid small hydro. In principle, the cost should be managed within the electricity tariff revenue.

6-3-5. **Operation and Management of Off-grid Small Hydropower**

Off-grid small hydropower stations in rural areas, which are supposed to be operated independently, must be managed by local people or local authority. In order to achieve sustainable long-term operation of off-grid small hydro, a comprehensive organizational development and staff training plan is essential. Therefore, a responsible management structure, qualified staff, and detailed operation and maintenance rules and practices must be developed by the developer based on the conditions of community.

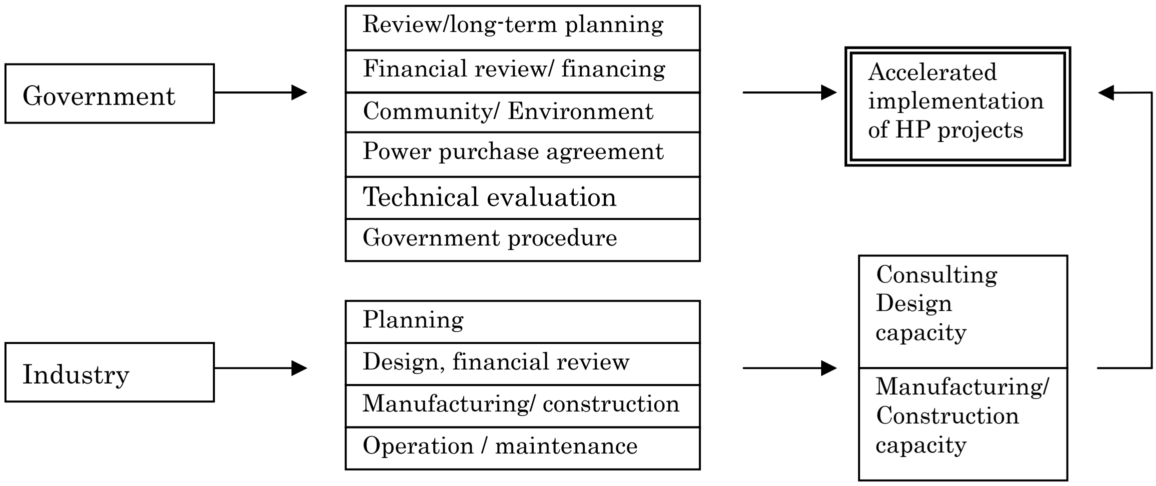
7. Model Plan for Off-Grid Small Hydropower Development

7-1. Necessity of Capacity Development

Community development by small hydropower is often regarded as an excellent development project that combines engineering and socio-economic development. In Uganda, the development of off-grid small hydropower has just started. The Kisiizi off-grid small hydropower project in Rukungiri District is near to completion with a strong support from the ERT program. The Bwindi project in Kanungu District is going to start soon with GTZ funding. There will be many more off-grid small, mini or micro size, hydro potential sites that are waiting for development in remote mountainous areas of Uganda.

Now, Uganda needs donors' assistance to develop off-grid small hydro projects to achieve the goal of raising rural electrification rate, and developing local communities and rural enterprises, because Uganda lacks hydropower planners and experienced hydropower engineers who can push off-grid small hydropower projects forward. The GOU and the private sector have little capacity to take an initiative in off-grid small hydro project now. To develop more off-grid small hydro projects, Uganda recognizes a strong need for human resource development, which is more urgent than securing necessary funds. Asking donors to build off-grid small hydro plants hardly provides learning opportunities for Uganda; therefore, Uganda can gain very little for the future. Hence, the highest priority issue is capacity development both in the public and private sector.

The GOU urgently needs to strengthen its administrative capability for promoting and coordinating hydropower development projects for the best interest of Uganda. Also, the business sector of Uganda, which is overlooking business opportunities in hydropower development, needs to develop technical capacity to be involved in hydropower development projects for business expansion.



Items for Capacity Development

7-2. Model Plan for Capacity Building

7-2-1. Capacity Building for Governmental Organization

Among the government organizations, the Ministry of Energy and Minerals Development (MEMD) and Rural Electrification Agency (REA) are the key players in hydropower development in Uganda. Hence, a comprehensive training program targeting the officers of these organizations needs to be developed and implemented. These organizations need to have a wide range of high level knowledge, from engineering to financing, about hydropower development.

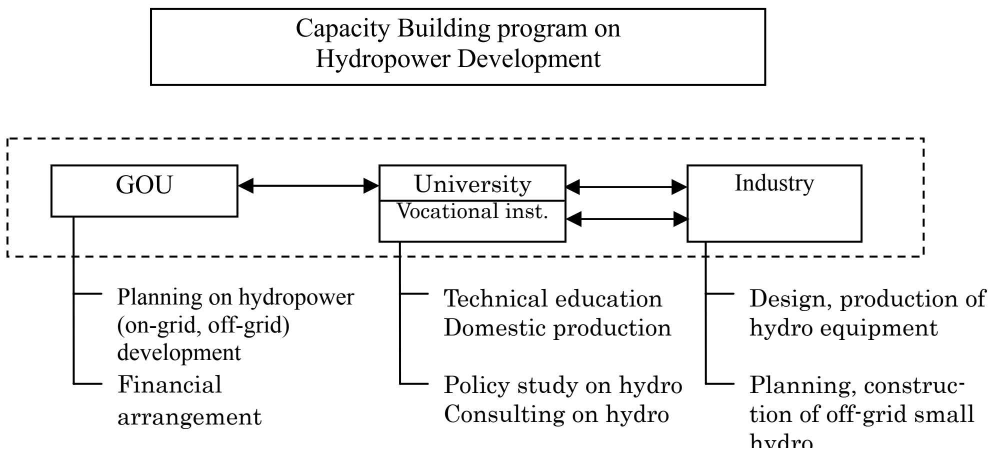
7-2-2. Capacity Building for Private Sector Engineers

Hydropower development is a multi spectrum business and technologies used in hydropower projects can be applied in various industries. The private sector of Uganda has almost no technical base on hydropower now, and hence, needs to learn from the basics. Therefore, it is required for the business sector of Uganda to have a strategic vision for capacity development on hydropower development, and the GOU should strongly support the capacity development activities. Also, it would be effective to learn from experiences of other countries. For example, Vietnam has developed good technical capacity on hydropower. Many hydropower plants are being developed now by local companies there. Thus, establishing a south-south cooperation between Vietnam and Uganda would be also effective.

When many educated engineers and technicians are developed and start to work in the fields of designing and manufacturing of hydropower equipment, some basic hydro equipment can be manufactured in Uganda. This will lead to acceleration of hydropower development and rural electrification, as anticipated. All of the relevant basic skills can be applied to other industrial/business fields as well, which will contribute to the overall development of Ugandan industry in the end.

7-2-3. **Organization Structure for Capacity Development**

The scope of capacity development program is very wide from technical theory to financial review. Even environmental consideration and community mobilization will be included. Hence, the program needs to be comprehensive, and many organizations should be involved. In particular, not only the government and private sector organizations, but also academic institutions, universities and vocational schools, are expected to be involved to make the national level capacity development program for hydropower. The academic institutions will act as knowledge center to oversee the overall capacity development program.



Recommendable organizational structure

7-3. **Combination with Off-Grid Small Hydropower Project**

It is very effective to carry out off-grid small hydro development projects in parallel with the capacity development program to provide opportunities of practical learning. A recommendable scenario is to identify suitable off-grid small hydropower sites with a capacity of 20kW to 100kW, and develop them in series. Many potential sites have been surveyed already. Small hydro of this size is good for community development, and easy to construct and find financial solutions, which is suitable for practical training. Large-scale hydro projects are not appropriate for this purpose.

Japan can dispatch experienced engineers, who had been involved in many hydropower development projects both in the country and abroad, as trainers or advisors. Also, Japan can assist in the fields of developing high level of skills in metal processing, molding, and electric or electronic engineering, etc., using its strong industrial background.

8. Recommendations to JICA

8-1. Development of Japanese consultants

JICA will be asked to play a leading role in renewable energy development targeting developing countries. However, there are very few consultants in Japan who have experience in off-grid rural electrification. Hence, JICA may have difficulty in hiring experienced quality consultants. Off-grid PV system and off-grid small hydropower projects are special topics that are no longer necessary in Japan. Therefore, new generation of consultants who can clearly address off-grid renewable energy application will be difficult to come out in Japan. Only JICA can develop such human resource with a long-term view.

8-2. International Collaboration

The world needs to tackle the global warming issue and international collaboration is extremely important. There are many international organizations and aid agencies that are involved in the projects for global warming mitigation and poverty reduction. JICA needs to build strong relationship with other organizations and to coordinate its programs with them.

8-3. Asia/Africa Cooperation

In Asia, there have been many projects conducted for off-grid rural electrification. Some of them are successful. African countries and aid organizations working in Africa can learn a lot from good practices found in those previous projects in Asia. JICA can play a pivotal role in strengthening the Asia/Africa linkage.

8-4. Participation of NGOs and volunteers

Off-grid rural electrification is a community oriented grass-root type project and involvement of community is indispensable. In this regard, NGOs and volunteers may be able to work with JICA for acceleration of off-grid rural electrification. JICA needs to build a good relationship with them and provide basic knowledge on PV and small-hydro to facilitate their participation in rural electrification projects.

8-5. **Information technology and PV system**

PV system can supply power to mobile phones and computers even in remote villages. With such information technology, rural people's life is sure to change. This relatively new issue of accelerating information technology introduction into remote villages and its impacts needs to be studied further.

8-6. **Human resource development in small hydropower**

Isolated small hydropower for community development is a supreme development project that requires broad technology and high-level of technical expertise not only in engineering but also in socio-economics. Quality staff is needed to develop this kind of project and make it sustainable. To develop such quality staff takes time in developing countries and well organized capacity building program should be implemented. In order to provide practical learning opportunities to local staff, development of a series of pilot projects should be considered.

8-7. **Multi sector approach**

Renewable energy development in rural communities has been primarily discussed in the context of providing home lighting as a basic human need. In reality, however, electric power can be utilized in many areas such as health care, education, water supply, information system, rural enterprise development, etc. Within JICA, many departments are related to those issues. Therefore, coordination efforts to cover relevant departments are necessary for better understanding of renewable energy and multi-sector project formulation utilizing renewable energy.