Comprehensive Analysis on Introduction and Dissemination of Photovoltaic Power Generation Technology for Developing Countries

Final Report

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0. Executive Summary

0-1. Grid-Connected PV Systems

Although grid-connected PV systems have long been mainly adopted in developed countries with fewer technical challenges and high electrification rates, JICA has been implementing projects to introduce PV systems on grid in about 30 developing countries since 2008 under grant aid.

More than 80% (17 out of 21 countries in the operational phase) of the projects were introduced as the first of its kind in their countries, and have played a pioneering role in the connection of PV power generation to their domestic power systems. Even in the countries where the on-grid PV systems are not the first cases, the installation also assisted their technological development by introducing systems with relatively large capacity in total.

The installation of the first grid-connected PV systems requiring technology transfers and technological guidelines contributed to reduce technological and institutional barriers for further promotion in the future. Some local officials mentioned that JICA's support for capacity building helped local technicians to operate and maintain the systems without relying on Japanese assistance. As a lesson, incorporating electric power companies in the management and maintenance system was suggested to be an important factor for stable operation of the facilities.

As in some countries, the existing Feed-in Tariff (FIT) policies were not essentially applied, the actual condition of policy implementation should be considered on introduction of PV systems.

Geographical conditions, such as island countries or inland countries with crossborder grids, are one of the main elements of decision making for the introduction of PV systems into each country. In small island countries where diesel generation has long been the only energy option, PV systems were introduced for the purposes of energy security and lessening financial burdens. On the other hand, some inland countries have regarded the augmentation of power generation facilities as opportunities to export electricity to neighbouring countries.

In short, besides technological aspects, elements such as geographical conditions, energy policies, and costs are also important aspects to be considered for the introduction of PV systems. According to surveys on the target countries, JICA's support has significantly contributed to solving technical and institutional problems regarding the introduction of grid-connected PV systems.

0-2. Off-grid Stand-alone PV Systems

Since the early 1980s, when even in developed countries PV technology was not applied so much and most development partners, including the World Bank group, had not started their activities in this field, JICA has supported developing countries by using PV technology (at first, PV systems with batteries as power sources for off-grid areas were applied). Along with other international organizations such as USAID and the EU, JICA can be seen as one of pioneers in promoting PV technologies toward developing countries, through its intermittent implementation since the early 1980s of grant aid-based small pilot projects such as water supply systems and telecom facilities.

From the 1990s on, in parallel, JICA has been involved in technological cooperation for stand-alone PV systems focusing on Solar Home Systems (SHSs) for individual households.

From the mid-1990s on, JICA has supported the development of comprehensive electrification master plans, including PV technologies with some pilot projects. As well, in the same period, JICA's support has been expanded to capacity development toward various stakeholders.

Regarding off-grid PV technologies targeting non-electrified households, such as SHS and Battery Charging Stations (BCS), we do not find notable expanding cases, except for those of Bangladesh (around 2.6 million SHSs) and Mongolia (around 0.1 million SHSs), in terms of the massive scale dissemination and sustainability that contribute solidly to electrification of off-grid areas. At present, few donors have come to take these approaches as new support measures.

However, donors, including JICA, have drawn many useful experiences and lessons from the past projects in terms of policy and planning, business models and management, and technology application. These experiences and lessons are expected to be references for future dissemination of PV technologies in developing countries.

In the case of the Pakistan project in the early 1980s, PV systems were installed in an area not included in the plan for grid expansion in 10 years. However, it was reported that after the project implementation, local residents had protested against the project due to the negative effect of the project on their village's grid connection priority The lesson drawn from this was that in order to implement stand-alone PV systems, it is effective to identify targeted off-grid areas based on national electrification plans and priorities of electrification. For example, in the cases of Cambodia and Laos, as a support for policy formulation and institutional development, comprehensive master plans for electrification were developed and prioritized off-grid regions of electrification were identified from a medium- and long-term perspective for realization of electrification step by step. It should also be kept in mind that PV systems may still play roles even after the area is connected to the grid, in situations of high grid connection fees and/or unstable grid power supply such as the cases of Bangladesh and African LDCs.

Regarding business model and management aspects, the case of the Republic of Vanuatu has shown us the importance of clarifying ownership of SHSs and responsibilities of operation and maintenance. Development of functionable management systems, existence of implementing agencies and providers with capacities and capacity building for technicians are also recognized as important factors. The Bangladesh SHS program, from which further expansion with JICA's co-financing is expected, has had outstanding experiences concerning these elements by integrating the flows of SHS installation/ after-care and finance/payment collection.

On the other hand, PV-based BCS projects managed by local communities have not been successful at all, with the exception of a few such as the countries with experiences of BCS through diesel gensets: this is due to obstacles including provision of initial costs, clarification of ownership and benefit incidence. On the other hand, there are some success stories of private-owned and -operated systems such as Kiribati SHS and Cambodian BCS. Some international organizations have been interested in community-level power supply systems with core demands of telecom base stations. It should be noted that, when personnel are reshuffled, some facilities and their management systems have not been sustained since the activity seems to depend greatly on the ambition of persons involved.

As for technology, from the nature of PV systems such as easy installations and short lead time for development, there was a trend from 2000 on of the introduction of PV systems in developing countries with the support of donors and international organizations riding on the strength of needs for climate change countermeasures. However, many cases reported that batteries failed within two years on account of overuse due to lack of user knowledge, such as in the case of Botswana. In addition to user problems, there were also some reports of malfunctions of PV systems caused by design defects due to the lack of technicians who understood the performance of PV technologies well, from donors and consultants too.

JICA's experiences—JICA's off-grid support actitivities have included software components of educating and training users and relevant stakeholders—have also taught us the importance of human resource development, capacity building and training for ensuring appropriate system design, components, and installation, as well as operation and maintenance (O&M).

In particular, the Philippine capacity development project (for SHS) in 2005 developed a tailored textbook reflecting local realities. Technicians trained by the project have also become responsible for the diffusion of PV technology internationally through playing active roles in south-south cooperation in several countries. The ongoing technical cooperation project for capacity development in Kenya most probably will have the same impact.

It is noted that JICA has not been directly involved in commercial-based “sales model” type projects in the market, including Pico-solar technologies with capacities less than $10W_p$. Therefore, although we have seen a large potential in this field, we treat this approach in this report in a limited fashion.

In a word, since the first half of the 1980s, JICA has worked on promotion and dissemination of PV technology toward developing countries as one of the pioneers in the field. Based on these nearly 30 years of experience, the following key factors can be concluded for introduction and dissemination of PV technology in off-grid areas:

- As a precondition for implementation of stand-alone PV technology projects, it is important that they be integrated with national grid expansion plans and electrification priority plans. A step-by-step electrification based on a comprehensive master plan for electrification and identification of priority areas of electrification and off-grid area from a middle and long-term perspective is seen as very useful. There are also cases of PV systems being used continuously even after electrification due to high grid connection fees and poor reliability of grid power supply services;
- It is important to clarify ownership and ensure operation and maintenance in the case of SHS and BCS projects. Moreover, formulation of management systems and existence of capable programme implementers and SHS providers, incentives for SHS providers and training of sufficient technicians to implement the programme are seen as also very important; and
- Regarding proper system design, components, installation, and O&M structure including systematic capacity development for training for technicians and users awareness activities have been seen as a key factor for project implementation.

Based on the above experiences, donors from developed countries and international organizations as well as relevant policy-makers in developing countries are recommended to take the following notes into account in their promotion of PV-electrification in off-grid areas:

- Consistent with overall policies/plans such as grid expansion plans and electricity tariff systems;
- Clarification of ownership for SHS systems for operation and responsibility for maintenance (selection of business models such as commercial sales models or fee-for-service models);
- Design and operation of a management system that integrates flows of finance and SHSs. Under an output-based piecework payment system, SHS providers are able to provide financial services for gaining corresponding benefits. Integration of regular checking of SHSs and payment collection can be realized and a competitive environment can be promised;

- Development of technical standards as well as warranty systems for SHS components and their manufacturers is useful. Technical risks, especially risks from selection of products, should not be imposed on the users; and
- Design and operation of a systematic human resource development program (*incl.* awareness campaign for users) is necessary.

I. Objectives of the Study

I-1. Background and Objectives of the Study

Since 1980, JICA has supported and promoted a large number of Photovoltaic (PV) power generation technology introduction and dissemination projects in developing countries. The projects include both:

- Off-grid (stand-alone) PV power generation, and
- On-grid (connected to grid) PV power generation activities.

The objectives of the survey are as follows:

- To clarify the findings, experiences and values of JICA's activities in PV power generation technology promotion and to extract our good practices and lessons from the activities, and
- To share outputs with government agencies, international organizations and private companies for their future involvement with PV power generation technologies in developing countries.

I-2. Past Experiences of JICA

Since the early 1980s, when even in developed countries PV technology was not applied so much and most development partners, including the World Bank group, had not started their activities in this field, JICA has supported developing countries by using PV technology (at first, PV systems with batteries as power sources for off-grid areas were applied). Along with other international organizations such as USAID and the EU, JICA can be seen as a leader in promoting PV technologies toward developing countries, through its intermittent implementation since the early 1980s of grant aid-based small pilot projects such as water supply systems and telecom facilities.

From 1990 on, in parallel, JICA has been involved in technological cooperation on the stand-alone PV systems focusing on Solar Home Systems (SHSs) for individual households.

From the mid-1990s, JICA has supported the development of comprehensive electrification master plans, including PV technologies with some pilot projects. As well, in the same period, JICA's support has been expanded to capacity development toward various stakeholders.

Since 2008, JICA has promoted on-grid PV technology system without batteries in roughly 30 countries under a grant aid program.

For most countries, there were initial difficulties. Considerable barriers from institutional issues and technical problems including reverse power flow were cleared and relevant experiences were accumulated.

PV technology promotion projects using Japanese ODA are shown in the figure below.

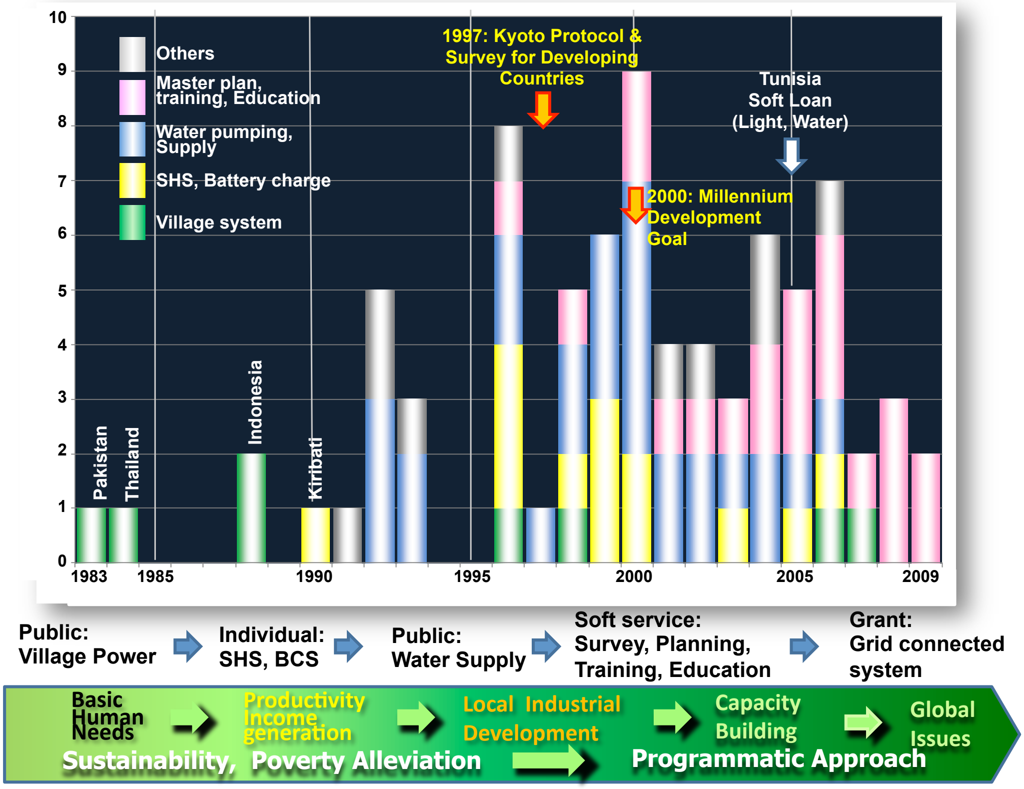

Figure 1: History of PV Support Projects Using Japanese ODA[1]

The PV technology promotion projects can be classified as follows.[2]

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[1] Source: Kazuo Yoshino's presentation material.

[2] Including PV technologies that are not included in JICA's support portfolio such as pico solar, on-grid rooftops other than public facilities.

Table 1: A Classification of PV Technology Projects

Grid Connection	Main Target	Users	Battery	Examples
Isolated	Households (for electrification)	Single household	Yes	SHS, Pico-solar
		Plural HHs (non-wire)		BCS, etc.
		Plural HHs (wire)		Mini/Micro-grid (subsystem)
	(Public) Facility	Single or a few facilities		Clinic, PBS, School...
			No	Irrigation, Well water...
Grid-connected				University, Airport...
	HH/Buildings/Industry	Building-unit		Rooftop; For fuel saving/emergency
	Grid			Mega Solar

It is noted that in most cases, isolated mini/micro-grid systems are mainly diesel gensets-based. PV systems, which cannot follow the load change, could serve as supplemental generators to reduce related diesel fuel costs.

II. Approaches of Stand-alone PV System

II-1. Concept of JICA's Support

In the 1980s, when most development partners including the World Bank group had not started their support of PV projects, JICA had already implemented grant-aid based stand-alone PV systems for the purposes of rural electrification and poverty alleviation. However, the projects had not produced a successful model.

In the 1990s, starting with the first SHS in Kiribati, many studies for technological cooperation including BCS were conducted. In the second half of the 1990s some pilot projects were also implemented.

The following figure shows the transition of approaches in the case of electrification.

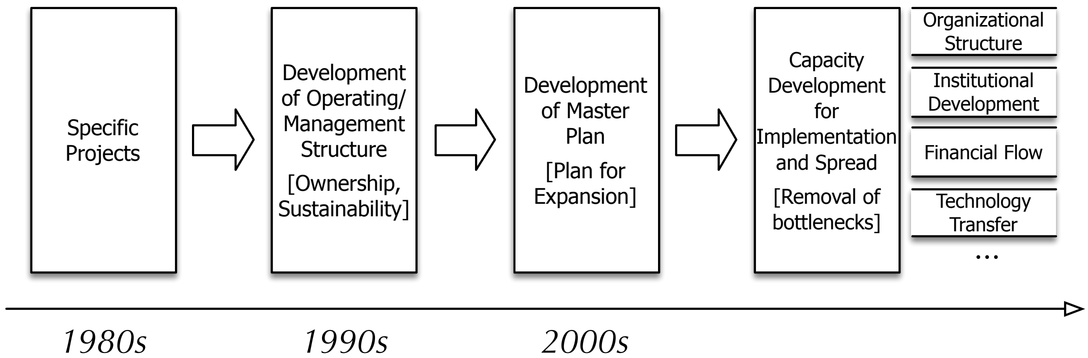


Figure 2: Transition of JICA's Approaches in the Case of Electrification

Based on the experiences from individual projects in the 1980s, the development of community-participation management systems was pursued in the 1990s. Projects aimed for clarification of roles of PV system suppliers and users, ownership awareness raising through facilitating fare collection systems, and sustainable application of the facilities. After that, through clarification of the management system, support for master plan development was conducted for disseminating the technology across the countries.

Recognizing that the knowledge and ability of policy makers and technicians had been a bottleneck for project implementation, JICA implemented support focused on capacity building in various fields.

In addition, PV systems introduction to water supply facilities, medical facilities and communication facilities in off-grid areas was also done based on grant aid.

Moreover, stand-alone PV systems have also been included in grant-aid based grass root/human security projects and recent feasibility studies of inclusive businesses for base-of-the-pyramid (BoP) people.

II-2. Forms of JICA's Support

JICA's approaches to renewable energy support are as follows. As shown in the figure below, JICA has conducted support for development studies and technical cooperation based on the flows of planning, implementation/dissemination and maintenance.

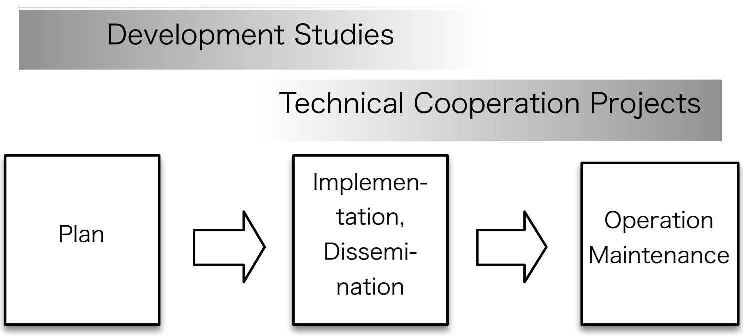


Figure 3: Development Studies and Technical Cooperation Projects by JICA

The followings are details of the support. Recently emerged are financing loans and incusive business for BoP people.

- Development studies to support development plan
  - Surveys (*incl*. potential);
  - Master plan development support (from PV-related program, rural electrification plan for comprehensive energy policy);
  - Individual policy program development such as technological standard establishment (incl. policies and measures such as introduction of FIT);
  - Business model development (financial plan, FS and specific design).
- Pilot projects/program implementation (technical cooperation)
  - Feasibility study (FS);
  - Pilot projects/development of program management and maintenance system (institutional development for dissemination; establishment of financial flow; awareness activities);
  - Pilot system installation (by grant) (O&M system, technical manuals);
  - Verification of the dissemination pilot projects/program.
- Capacity development and training

  - For policy-makers;
  - For engineers (training for trainers);
  - PV technology textbook and manuals development for stakeholders including users.
- Financial loan for specific programs/projects (two-step loan type)
- Support for inclusive business for BOP people by Japanese companies

The following are examples of the task flows for maintenance systems development and dissemination policies discussion:

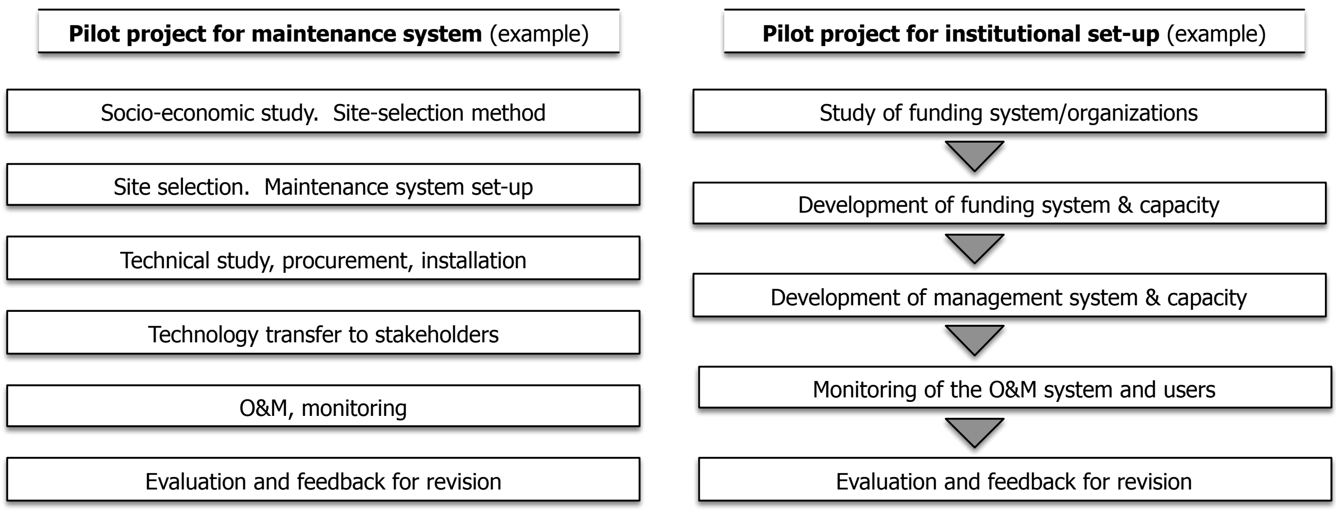


Figure 4: Examples of O&M System for Pilot Project and Institutional Set-up

Since 2013, JICA has been providing a co-financing loan for the Bangladesh SHS program.

Generally, the support is implemented through the combination of several components. In particular, capacity development belongs to other approaches in most cases. Some approaches refer to the whole renewable energy field rather than specified PV systems alone.

The following is the case of Ghana. At first, current problems were recognized through surveys for rural electrification master plan development. Based on the results of the survey, a project design was done and several experts were dispatched associated with technology and management. PV systems not only for households but for medical centers, schools, water supply stations and local industries have been proposed also and it is confirmed that they have played important roles.

Capacity development is generally conducted in host countries. There is also a two-month training program in Japan. In some cases, it is conducted in the form of cascading south-south cooperation, such as the case in which trained Filipino experts visited Bhutan, Zambia and others for training locals.

	2005	2006
	Development studies	Technical cooperation projects
Scheme	The Master Plan Study on Rural Electrification by Renewable Energy Resources	(Experts in multiple fields) Organizational systems, village development (non-technical) Solar Power (technical) Pilot projects
Activities	● Understanding of the problems in Ghana, such as the policies, organizational systems, and solar technologies; and the proposal of measures for improvement	● Technical transfer focused around diversified organization management, such as organizational systems and the improvement of the technical level, from the viewpoint of the development of the society (including pilot projects)
Features	● Possibility of the extraction of diversified problems and information sharing ● Necessity of new technical cooperation (beyond technical fields) towards implementation	● Efficient technical cooperation based on comprehensive proposals ● Need for experts from both the technical and non-technical aspects

Figure 5: Development of Renewable Energy Program (Ghana case)

The capacity building programs attempt to support endogenous development covering different stakeholders at different levels as much as possible by stimulating interaction between them.

Moreover, there are follow-ups and evaluations for Malawi, Bangladesh, *etc*.

II-3. Pre-electrification

Generally, grid-based electrification is seen as the best from its stability, capacity and reasonable cost. That means that stand-alone PV systems are a temporary step also called *pre-electrification* before reaching grids.

JICA's follow-up surveys have reported that households no longer used SHSs after they reached the grids. This implies that SHS system introduction projects need careful consideration.

However, from the following points, it is worth promoting electrification through stand-alone PV systems provided that there is no clear and reliable plan for grid connection to the area in the near future:

- There is a priority for basic human needs during human development;
- Lack of electricity even in the short term leads to big opportunity losses such as educational opportunities for children (timing is very important in children's education) and loss of income generation opportunities such as running small

shops and making handmade crafts at night;

- Grid expansion will be accelerated along with economic development and access to electricity in turn will stimulate economic development also;
- PV systems can be reused in other off-grid areas when no longer used in one area where the grid has reached;
- In the case of unstable grid systems, PV systems can be used as backup;
- In LDCs, there is still a significant number of households which cannot access grids because of high connection fees and high wiring fees; and
- Credibility of grid expansion plans is not so high in most developing countries. There are many cases in which grids have still not come several years after the year specified in the plan.

In a word, pre-electrification through PV systems is worth being implemented if it is believed to have instant results, even if its function will last only a couple of years. On the other hand, it should take into account and be consistent with the electrification master plan. This is the reason why JICA focused on supporting master plan development in the 2000s.

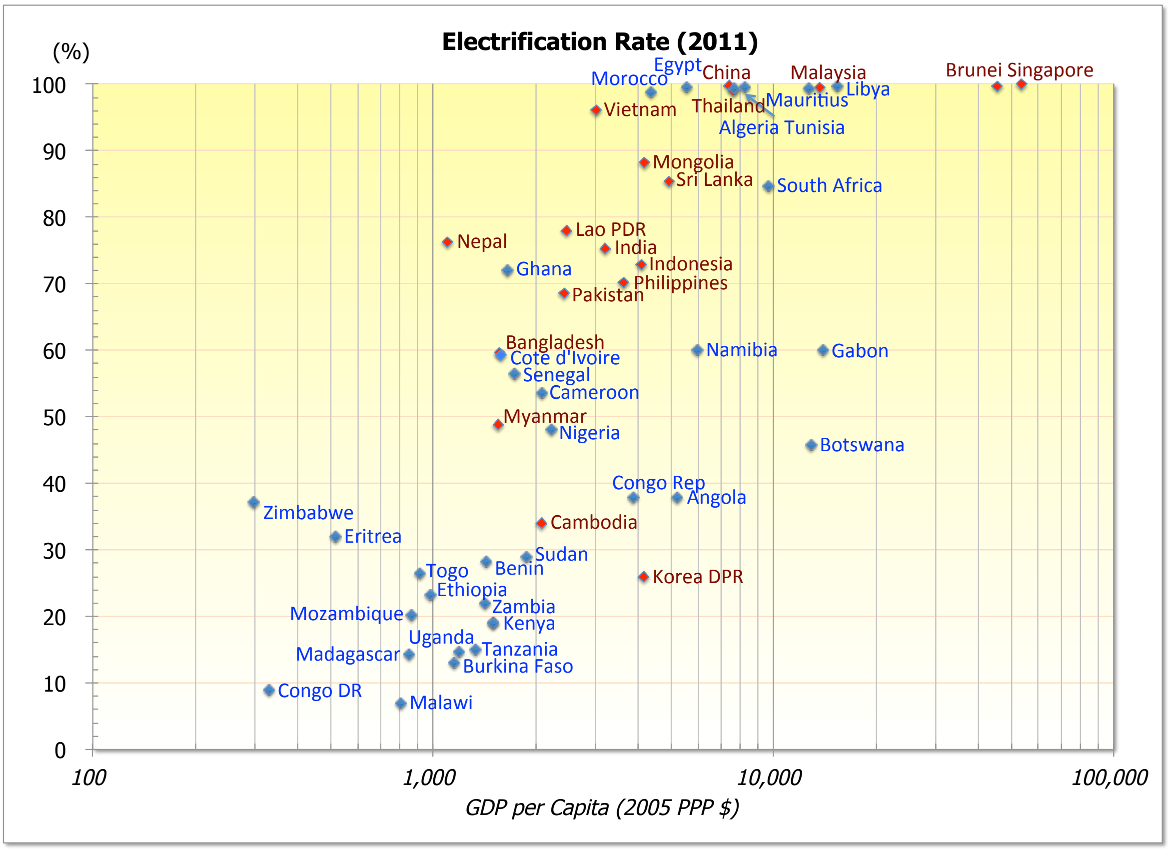


Figure 6: Electrification Rate and GDP per Capita (WEO2013 database, IEA)

From the figure above, it is widely seen that electrification rates increase along with GDP per capita (except for some countries). Comparing Asia with Africa, Asia has higher electrification rates than that of Africa against the same GDP per capita. The following points are postulated reasons.

(1) Population density in Asia is higher than that of Africa, and

(2) Power development and grid expansion plans work well.

In Bangladesh, so far 2.6 million SHSs have been installed, comprising 10% of the total households and 25% of the off-grid population.

II-4. Shared-type Systems such as BCS

JICA's past projects include some Battery Charging Station (BCS) pilot projects owned and operated by a local community or private enterprise. Users owned the batteries in most cases.

The BCS model is notable for not requiring distribution lines. It is seen as a market-driven model and mostly occurs at the end of grids, using diesel generators.

In Cambodia, where the model has been applied for a long time (by using diesel generators), users' capacities and experience with using lead acid batteries ensured the possibility of the model. Owners and operators of the electricity generation systems have run the BCSs for business puposes.

However, in Africa, there were many cases in which communities were the owners and operators of the systems, causing problems with fare collection and maintenance due to the unclear ownership concept. Finally most projects ended in failure.

The initial cost of PV systems with capacity of several kW_p is a big challenge also when introducing service models with PV systems.

On the other hand, tiny service models like mobile phone charge services using PV systems are found easily in most developing countries.

II-5. Experiences of SHS

SHS refers to a system consisting of a solar panel with capacity around $50W_p$, a charge controller, a battery (deep cycle type) and demand side devices like CFLs or LEDs. There are attached mobile phone charging terminals also. Providers are responsible for installation and required to have technical skills at some level.

A big difference between SHS and BCS is that the SHS has a single user, who owns and operates the system. Providers sell the systems and are in charge of installation and maintenance (*i.e.*, sales model, in many cases). Experiences of SHS also showed that after-care correspondence was a problem in many cases of SHS programs not working well.

The price of a SHS is around several hundred US dollars, equivalent in some countries to several times yearly household income. Therefore, initial cash payment by households is very limited. In most cases, programs are being run in the following way with financial support from donors and international organizations such as the World Bank:

- Subsidy, and
- Loan with installment.

II-5-1. Bangladesh SHS Program (most expanding case in SHS)

The Bangladesh SHS program, which has installed 2.6 million systems so far and installs 2,000 systems a day, is seen as the most expanding ongoing SHS program. It plans to install 4 million SHSs by 2015.

Infrastructure Development Company Limited (IDCOL), a semi-governmental non-bank finance institution, has been implementing the program with financial assistance from the WB, GEF, KfW, ADB, IDB and JICA. Private companies and NGOs called Partner Organizations (POs) have been responsible for installation and maintenance of SHSs as providers. Grameen Shakti is one of the largest POs under the program.

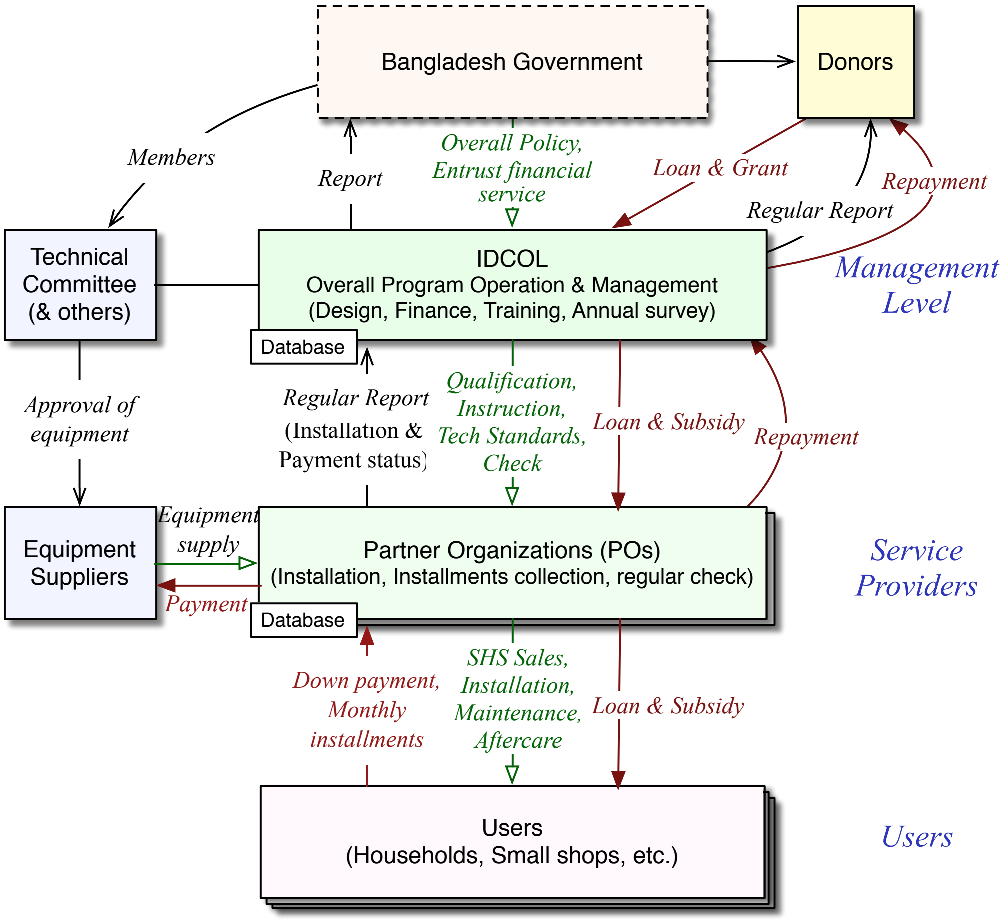


Figure 7: Structure of Bangladesh SHS Program

Installation/O&M processes of SHSs and financial flow are integrated together in the program. Namely, IDCOL has provided financial services to POs by utilizing finances from donors. POs in turn are providing micro credits to their end users. Under IDCOL's management system, POs have to provide a monthly report to IDCOL concerning the status of installation (SHS flow) and loan payment (financial flow).

In addition, POs are responsible for checking the operating condition of systems through checklists together with monthly visits to households for payment collection. The self-developed management scheme enables IDCOL to grasp situations in each individual household such as SHS installation/operation/maintenance *as well as* the payment of installments.

Moreover, besides information from POs, IDCOL has been conducting independent annual surveys that play a PDCA process in the program operation. A quality control mechanism for services also enables users to contact IDCOL for any complaints about the services.

Nevertheless, the program needs a lot of technicians. Therefore, POs and IDCOL have their own training systems. For example, Grameen Shakti, the largest SHS provider, is running 46 Grameen Technology Centers with training programs mainly for low-income women from villages. Training includes not only installation of SHSs but also the skills of assembling the charge controller and mobile chargers.

The Program is designed carefully to realize the following conditions:

- A scheme which users can afford, and
- A scheme in which providers can manage to stay in business.

In the program, users can obtain a SHS by 15% down payment and 36 installments in 3 years (less than the battery lifetime). Thus, for example, an initial payment for a $50W_p$ system becomes around 50 US dollars. The subsidy scheme (US$25/SHS) has almost concluded at the moment except for the smallest $20W_p$ systems that appear more welcomed by most households now.

On the other hand, providers can gain 80% (now down to 70%) of the micro credit finance from IDCOL with 1–2 years holding period and 6–9% annual interest. The payback period is set to be 5–7 years. It is noted that a result-based incentive scheme is applied for the SHS providers (and also for IDCOL).

That is, an interest rate difference generates income for providers. As mentioned before, providers also need to prepare 20% (so far it is 30%) of the total activity cost. At the beginning, there was a subsidy scheme for providers such as US$3/SHS. However, at the moment the subsidy scheme has been terminated for existing POs (new POs can still have the subsidy). Several POs have been competing to sell SHSs even in the very remote areas now, as we find several SHS providers even in far remote areas.

The Bangladesh model has been recognized as a good example of application of Output-based Aid (OBA)[3]. The OBA approach is used in two stages, such as donors to IDCOL and IDCOL to SHS Providers. The OBA has functioned very well in the program as it provides incentives for providers to improve their performances.

The providers, like Grammen Shakti, are able to get financing from IDCOL for their next customers based on their completed SHS installations without waiting for the capital to be collected. Sources of the financing are grants and soft loans from the World Bank and other donors. Thus providers can obtain benefits from their financial services that are attributed to low cost financing from IDCOL, ultimately from donors and other international organizations.

In order to run the program successfully, providers should have a certain financial capacity so as to ensure the initial outcomes and sound management systems. For this, IDCOL has set up several conditions for POs, such as (1) financial capacity with at least 10 million Taka capitals, (2) indebtedness not more than 3 times the capital, (3) at least 10,000 customers, and (4) publishing financial reports externally audited on a yearly basis.

At present, $20W_p$ systems are replacing $50W_p$ as the dominant model. One of the main reasons is diffusion of LEDs instead of CFLs, in addition to the existence of the subsidy shown above. Application of LEDs cuts the electricity consumption by 50% (7W CFL and 3W LED can give the same 250 lumens) and enables households to get the same service level as $50W_p$ with $20W_p$. Increased buying trends among lowest income groups may be another reason for the increasing share of $20W_p$.

The product assurance system of the program has also functioned effectively to shift the risks from the users to the manufacturers/providers and it is recognized that most SHSs have been working well. IDCOL manages household-based information including results of monthly checking and complaints from households.

II-5-2. Examples of Cases with Issues

In Ethiopia, the second largest populated country in Africa, the electrification rate is around 23%. Even in the grid area, there are still many households not on the grid because of the high connection fees.

Since 2011, the SHS program has been implemented with the support of the WB. So far, 2,500 SHSs have been installed. The percentage of malfunctioning SHSs is supposed to be high; however, the government and program supervisors have not ascertained the figure so far.

In the case of Ethiopia, local goverments are taking the main roles in introduction of systems. Users are required to form an organization to apply for SHS systems. Although

[3] https://www.gpoba.org/node/700.

the local government offices have the information on installations of each SHS, they seem not to have a grasp of the operation status of the SHSs. The central government office has not collected information from local offices so far in detail.

Also, financial information like loan payment conditions is not shared with the agencies responsible for installation of SHSs. As a result, program management does not function effectively and information collection is also not satisfactory. The donor, the WB (WB's finance is injected into the Ethiopian Development Bank, which is not directly involved in the program) has also not gained enough information on the program.

User education is also an important element. There are some cases of SHSs being left in the field after malfunctions caused by inappropriate application such as overuse of demand AC appliances (color tube-type TVs) with inverters. It is also reported that users face trouble getting in touch with providers for their complaints.

In Asia, in the cases of Cambodia and Laos, with rapid grid expansion room for SHS application has been narrowed to remote areas such as the limited mountainous regions.

In Cambodia, around 1,000 SHSs are installed a year. Moreover, the WB has frozen its finance support temporarily. A company called PicoSol is playing the roles of technology provider and trainer of local entrepreneurs, with financial support from the Dutch government. Though PicoSol has been pushing a scheme using microfinance institutions, its coverage is seen to be limited at the moment.

In the case of Laos, JICA's report in 2005 took it as a successful project. There is also a program supported by the WB. As a result, 9,000 SHSs were installed in 2006–2010 and 15,000 SHSs were installed in 2010–2013. It has now been decided to continuously support low-income households (around 5% of total households) in remote mountainous areas. The Sunlabob Company has developed a fee-for-service model in Laos. However, this model is now inactive due to the government's objection to price hikes actually indispensable for sustainable maintenance. The remaining 10% of the total households are planned to be covered by SHS and micro hydropower generation systems.

From JICA's experiences, technical issues emerge as crosscutting challenges. Generally, PV systems are apt to be seen as easy technology. There were many examples of batteries which suffered trouble after a short time due to overuse arising from lack of technical capacities of technicians and insufficient understanding of users. The fact is that the number of technicians who precisely understand the mechanism of offgrid PV systems is limited among both donors and consultants. As a result, deficiency in proper system design and faulty workmanship caused malfunctions of systems within a short time. JICA has conducted support emphasizing the soft components that include human resource development, capacity building, and training to foster technicians with appropriate design and problem solving abilities.

The Philippine capacity building project in 2005 developed a tailored PV textbook. Technicians trained by the project have also become responsible for diffusion of PV technology internationally through playing active roles in south-south cooperation in several countries.

II-6. Findings and Implications

In short, since the first half of the 1980s, JICA has worked on promotion and dissemination of PV technology toward developing countries as one of the pioneers in the field. Based on these nearly 30 years of experience, the following key factors can be concluded for introduction and dissemination of PV technology in off-grid areas:

- As a precondition for implementation of stand-alone PV technology projects, it is important to integrate them with national grid expansion plans and electrification priority plans. A step-by-step electrification based on a comprehensive master plan for electrification and identification of priority areas of electrification and off-grid area from middle- and long-term perspectives is seen as very useful. There are also cases of PV systems being used continuously even after electrification due to high grid connection fees and poor reliability of grid power supply services;
- It is important to clarify ownership and ensure operation and maintenance in the case of SHS and BCS projects. Moreover, formulation of management systems and existence of capable programme implementers and SHS providers, incentives for SHS providers and training of sufficient technicians to implement the programme are seen as also very important; and
- Regarding proper system design, components, installation and O&M structure, systematic capacity development for training for technicians and user awareness activities have been seen as a key factor for project implementation.

Based on the above experiences, donors from developed countries and international organizations as well as relevant policy-makers in developing countries are recommended to take the following notes into account in their promotion of PV-electrification in off-grid areas:

- Consistent with overall policies/plans such as grid expansion plans and electricity tariff systems;
- Clarification of ownership for SHS systems for operation and responsibility for maintenance (selection of business models such as commercial sales models or fee-for-service models);
- Design and operation of a management system that integrates flows of finance and SHSs. Under an output-based piecework payment system, SHS providers are able to provide financial services for gaining corresponding benefits. Integration of regular checking of SHSs and payment collection can be realized and a

competitive environment can be promised.

- Development of technical standards as well as warranty systems for SHS components and their manufacturers is useful. Technical risks, especially risks from selection of products should not be imposed on the users;
- Design and operation of a systematic human resource development program (*incl*. awareness campaign for users) is necessary; and

III. Analyses of Grid-Connected PV System Projects

III-1. Overview

JICA has funded about 30 grid-connected PV systems in developing countries through Japan's Program Grant Aid for Environment and Climate Change since 2009, mostly as pioneering cases in their countries. Among about 30 projects, this study selected 21 projects which had started their operation by 2013 (Table 2) to investigate their conditions and experiences regarding both installation and operation.

Unlike off-grid PV systems, grid-connected systems are only available in the electrified regions, requiring engineers with solid knowledge of electric power systems and grid interconnection. Accordingly, the selected sites are all in populated regions, mostly metropolitan areas.

Table 2: Installation Projects of Grid-Connected PV Systems by JICA

No	Country	Region	Location	System Site	Capacity (kW_p)	The First Grid-Connected PV System in the country	Precedent
1	Mongolia	Asia	Airport	Chinggis Khaan International Airport	443.52	Yes	
2	Palau	Oceania	Airport	Palau International Airport	225	No	EU, Taiwan
3	Djibouti	Africa	Research Institute	Centre d'Etudes et de Recherche de Djibouti	300	Yes	
4	Afghanistan	Asia	Airport	Kabul International Airport	250	Yes	
5	Tajikistan	Asia	Hospital	Diakov Hospital	120	Yes	
				Laboratory of Obstetrics and Gynecology	40		
6	Marshall Islands	Oceania	Hospital	Majuro Hospital	208.98	Yes*	USA
7	Nepal	Asia	Reservoir	Kathmandu Valley Water Supply Management Board	680	Yes	
8	Maldives	Asia	Public buildings	President's Office	20	No	UNDP
				Maldives Center for Social Education	100		
				STELCO Building	45		
				Thaajuddeen School	130		

				Hiriya School	100		
				Velaanaage Building	40		
				Giyaasudheen School	80		
				KalaafaanuSchool	85		
				Maldives National University (Administrative Building)	40		
				Maldives National University (Health Sciences)	35		
				Hulhumale Hospital	(Total:65)		
				Ministry of Finance			
9	Uruguay	Latin America	Power Plant	Salto Grande Hydroelectric Power Plant	480	Yes	
10	Pakistan	Asia	Government	Planning Commission	178	Yes	
				Engineering Council	178		
11	Belize	Latin America	School	University of Belize	480	Yes	
12	Palestine	Mideast	Collective farm	Jericho Agro-Industrial Park	300	Yes	
13	Laos	Asia	Airport	Wattay International Airport	236	Yes	
14	Cambodia	Asia	Water Purifying Plant	Phum Prek Water Treatment Plant	777	Yes	
15	Burundi	Africa	Hospital	Centre Hospitalo-Universitaire de Kamenge	400	Yes	
16	Malawi	Africa	Airport	Kamuzu International Airport	830	Yes	
17	Ghana	Africa	University	University of Ghana	315	No	
18	Micronesia	Oceania	Government, University	Government Office	20	No	EU, Iceland
				College of Micronesia	160		
19	Gabon	Africa	University, Government	University of Omar Bongo	130	Yes	
				Ministry of Foreign Affairs	70		
20	Lesotho	Africa	Airport	Moshoeshoe I International Airport	280	Yes	
21	Moldova	Europe	Research Institute	National Oncology Institute	289	Yes	

*Originally installed as an off-grid system

III-2. Classification

The selected 21 projects were classified by aspects collected through interviews and questionnaire surveys addressed to the Japanese consultants and relevant professionals in the selected countries, as well as literature reviews on previously published reports and papers:

a. Background information
   - Governmental policies on energy
   - Circumstances of energy sector

b. Operational information
   - Related parties
   - Location
   - Specifications
   - Operation and maintenance

c. Analytic information
   - Pioneering roles
   - Impacts
   - Promising aspects
   - Troubles and handling
   - Guidelines
   - Technology transfer

III-3. Method

As shown in the previous section, the data and information for this study were collected through questionnaire surveys and interviews with involved professionals both in Japan and selected countries, as well as through summarizing existing reports and papers (Table 3).

Table 3: Methods for this Study

	Description
Literature Review	Reviews of reports and papers on previous studies by JICA and other organizations, *etc*.
Interviews	Interviews with Japanese consultants involved in JICA's PV installation projects.
Questionnaire Surveys	Surveys addressed to Japanese consultants and professionals in the installation countries who are responsible for installation and operation.
Field surveys	Site visits and interviews with professionals involved with PV systems in Mongolia, Palau, and Maldives.

The interviews with four Japanese consulting companies were conducted to obtain details on project conditions of 16 out of the selected 21 cases. The questionnaire surveys for all

21 countries, including the ones without interviews, were also used to receive the finalized designs of the installed PV systems, because many cases experienced changes, mostly increases in the capacity and the number of PV modules mainly due to the massive price reduction of PV panels.

The investigation team also visited some sites and interviewed local professionals in the countries with typical good practices: Mongolia, Palau and Maldives. The island countries, Palau and Maldives, were selected because of the high impact of renewable energy on their energy security, given that both are highly dependent on imported diesel. On the other hand, Mongolia is a non-island country where JICA's project was the first grid-connected PV case and also where the Feed-in-Tariff system to renewable energy is available.

III-4. Field Survey

III-4-1. Mongolia

The PV site in Mongolia is located within Chinggis Khaan International Airport, with good prospects of educating citizens on renewable energy. In Mongolia, almost 100% electrification has been achieved in the regions for settled citizens, and off-grid PV systems had been common especially among nomads thanks to the World Bank's National 100,000 Solar Ger Electrification Program, to which Japan also contributed.

JICA's system, the first grid-connected PV system in Mongolia, was not eligible for the FIT privilege because of its smaller capacity than the requirement, 1.5MW_p. Mongolian National University plans to study the data obtained from this first PV system to encourage further installation of grid-connected PV systems. By 2013, the only renewable energy power plant registered for the FIT in Mongolia, Salkhit Wind Farm, was reported to have raised electricity prices in the country by about 4%. The stability and impact of the FIT system should also be screened when application of FIT is considered.

Figure 8: PV Modules at Chinggis Khaan International Airport, Mongolia

III-4-2. Palau

In 2009, Palau announced a national plan to raise the share of renewable energy in electricity supply to 20% by 2020. As an island country, their high dependence on imported fuels is considered to be a risk in light of energy security. The promotion of renewable energy is beneficial for energy independence, as well as for mitigation of climate change.

JICA's project in Palau was installed as the third grid-connected PV system for the country, following systems installed by the EU and Taiwan. While JICA's system is being operated and maintained by the national power company, the preceding PV systems have been operated by the facility owners who are not familiar with maintenance of power systems, resulting in delays in repair and maintenance. The involvement of power companies in JICA's project can be noted as an advantage in view of reliable maintenance and operation.

Figure 9: PV Modules at Palau International Airport

III-4-3. Maldives

Maldives is also largely dependent on imported fuels, and energy security is one of the major concerns for the country. In 2010, the Maldivian president announced that the country would pursue 100% carbon neutrality by 2020. Even after his resignation and the recent change of administration in 2013, the view of a senior official of the Ministry of Energy and Environment is that the government will continue its promotion of renewable energy.

Among the supporting measures for PV systems, the FIT for PV in Maldives is currently planned to be renewed from the existing system, which is applied only to a single case.

In Maldives, JICA has installed ten grid-connected PV systems; two more are planned in the metropolitan area. Although JICA's project was the second on-grid project in Maldives, the accumulation of the 12 systems, 740kW$_p$, is the largest contribution by a single donor.

The 16 engineers at the state-owned power company (STELCO), who received training sessions by JICA, are currently operating and maintaining the PV systems without any help from Japanese engineers. According to the Ministry of Energy and Environment and

STELCO, the training sessions were highly appreciated for successfully raising the level of engineers.

The installation sites include schools, the Presidential office, and the only university in Maldives, which are also suitable for promoting renewable energy to citizens including children.

Figure 10: PV Modules at Thaajudeen School, Maldives

III-5. Analyses and Discussion

Among the collected data from various sources on the 21 projects, the most commonly available elements are listed in Table 3.

As background information on policy and power conditions, the availability of FIT systems in each country and reverse power flow at the installation sites are considered to indicate general circumstances for PV promotion. According to the reviews, seven countries currently have FIT systems or plans, but as known from the field surveys in Mongolia and Maldives, even the existing systems are not always sufficiently promoting PV systems. Their application conditions would be necessary information for private PV related-agents exploiting a new market to make adequate decisions.

The location and mounting types are listed as a part of the operational information. All sites in the series of the projects were owned by public sectors or semi-public utility sectors, and many of the locations were selected to maximize citizen education regarding renewable energy. Among the 21 countries, rooftop modules were installed in the island countries where flat spaces are limited, but also in some sites susceptible to theft such as Cambodia and Laos.

The analytic information includes availability of technical guidelines and whether JICA's project was the first on-grid PV system. In some countries, guidelines on PV systems were prepared by other JICA projects. Even if detailed technical guidelines have not been officially established, at least these operating projects prove that the local and Japanese engineers successfully shared the necessary techniques for on-grid PV systems.

Table 4: Classification of 21 Grid-Connected PV Projects

No.	Country	Background		Operational Information		Analytic information	
		FIT	Reverse Power Flow	Location	Mounting types	Technical Guidelines	First on-grid PV system
1	Mongolia	Yes	Yes	Airport	Ground	No	Yes
2	Palau	Yes	Yes	Airport	Roof	Yes	No
3	Djibouti	Planned	Yes	Research Institute	Ground	No	Yes
4	Afghanistan	No	N/A	Airport	Roof	in process	Yes
5	Tajikistan	No	No	Hospital	Ground	No	Yes
6	Marshall Islands	No	Yes	Hospital	Roof	N/A	Yes*1
7	Nepal	No	Yes	Reservoir	Ground	Yes	Yes
8	Maldives	Yes	Yes	Public Buildings	Roof	Yes	No
9	Uruguay	No	Yes	Power Plant	Ground	Yes	Yes
10	Pakistan	No	Yes	Government	Ground	No	Yes
11	Belize	No	Yes	University	Ground	No	Yes
12	Palestine	Yes	Yes	Collective Farm	Ground	Planned	Yes
13	Laos	No	Yes	Airport	Roof	No	Yes
14	Cambodia	No	No	Water Purifying Plant	Roof	No	Yes
15	Burundi	No	Yes	Hospital	Ground	No	Yes
16	Malawi	Planned	Yes	Airport	Ground	No	Yes
17	Ghana	Yes	Yes	University	Ground	N/A	No
18	Micronesia	No	Yes	Government , University	Roof	N/A	No
19	Gabon	No	No	University, Government	Ground	No	Yes
20	Lesotho	No	Yes	Airport	Ground	Planned	Yes
21	Moldova	No	No	Research Institute	Roof, Ground	N/A	Yes

*1 Originally installed as an off-grid system

III-6. Summary

This section reviews the 21 JICA projects funded by Japan's Program Grant Aid for Environment and Climate Change to install on-grid PV systems in developing countries on Table 1. The installed systems by JICA were the first case of grid-connected PV systems in more than 80% of the selected countries. These pioneering cases contributed involved engineers and organizations to experience the necessary procedures and techniques for connection. The projects cooperating with the local electric companies suggested that their involvement contributed to stable operation and reliable maintenance.

Although many of the selected countries are promoting renewable energy and some have privilege systems such as FIT, some of the interviews with local professionals revealed that those systems do not always attract investments even in these countries. These results indicate that the implementation status of supporting systems is indispensable as well as its existence. The mounting types, roof-top or ground, are dependent on surrounding circumstances, such as islands without enough flat fields, and areas susceptible to vandalism. Their site locations, which are all at public buildings or semi-public organizations, also help further promotion of PV systems to the public. Overall, the projects proved that these countries successfully obtained a fundamental basis for further installation of PV systems, by training local engineers and following established technical guidelines through JICA's projects.

IV. Messages to Practioners in Developing Countries and Development Partners

IV-1. Getting Started

IV-1-1. PV Systems in Development Cooperation

Since the beginning of the 1980s, when PV systems were rare even in developed countries and PV cooperation by most of developing partners such as the World Bank had not begun, JICA has conducted many international cooperation activities using photovoltaic (PV) technology. PV power generation is a clean, zero carbon and indigenous power source. It is also an appealing power source for developing countries, given its short development lead-time and low running costs. Currently, around a third of people in rural areas of developing countries have no access to electricity. PV systems are a promising electrification measure which has immediate impacts and provides opportunities for education and income generation.

However, it is necessary to make a proper judgement through comparing it with other power sources, as the total economic performance of PV power generation is still poor due to high initial costs and need for system stability measures possibly with additional electricity storage systems.

The PV system can be categorized into several types as shown in the table below.

Table 5: Types of PV Systems

Grid Connection	Main Target	Users	Battery	Examples
Isolated	Households (for electrification)	Single household	Yes	SHS, Pico-solar
		Plural HHs (non-wire)		BCS, etc.
		Plural HHs (wire)		Mini/Micro-grid (subsystem)
	(Public) Facility	Single or a few facilities		Clinic, PBS, School...
			No	Irrigation, Well water...
Grid-connected				University, Airport...
	HH/Buildings/Industry	Building-unit		Rooftop; For fuel saving/emergency
	Grid			Mega Solar

Here, we share the lessons learned from JICA's 30 years' experience of PV technology promotion with related parties from public institutions in developing countries and international organizations.

IV-1-2. JICA's Approach to PV Technology

JICA has conducted various support activities including trial and error in the PV field from the early stages of PV technology. Based on the early experiences of specific projects such as rural electrification, JICA identified the key elements of the O&M system. This was followed by support for design of the systems, development of master plans, and capacity development of various stakeholders, which could be the bottleneck for effective implementation/expansion of the program.

The following figure shows a transition of approaches in the case of rural electrification mainly by using SHSs. Many cases included pilot projects of SHS installations.

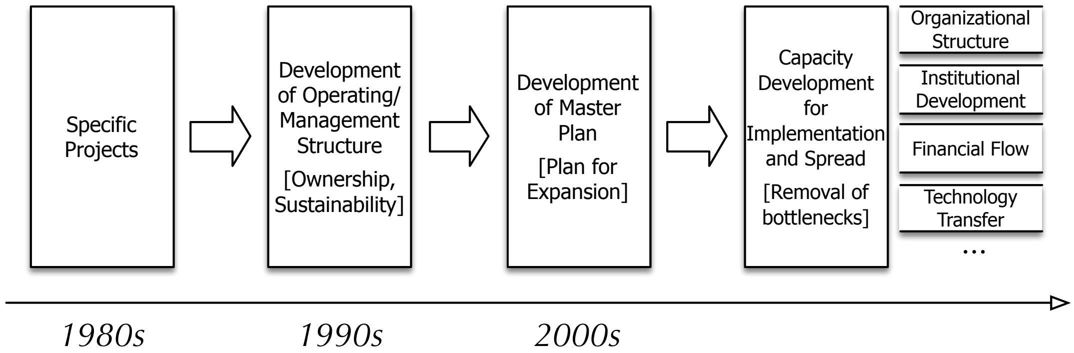


Figure 11: Historical Change of JICA's Support Activities for Rural Electrification

The reason why the approach shifted from specific projects to the development of electrification master plans was that JICA discovered the importance of keeping the projects consistent with national electrification plans and policies from the middle/long-term perspectives. In Pakistan, JICA experienced complaints by locals who claimed that grid expansion to their area had been delayed or canceled due to the existence of the PV system (SHSs) supported by JICA, even when the area was outside the grid expansion plan for more than 10 years.

> *Lesson Learned 1*
>
> Off-grid PV system programs should be consistent with overall policies/plans such as grid expansion and electricity tariff systems

In addition, PV programs are much influenced by the tariff of grid electricity, which is highly subsidized in many cases.

Through follow-up assessment of the projects, JICA also learned that capacity development for all stakeholders from policy makers to user households is essential for disseminating PV technologies, policy formulation and program operation. To this end, JICA has prepared textbooks and other materials that can be seen as good practices.

Nowadays, JICA has started co-financed renewable energies promotion, especially the SHS program in Bangladesh. This program is the most expanding SHS program, having installed 2.6 million SHSs to date and 2,000 SHSs per day. Although SHS technology is rarely chosen as a new channel for support of rural electrification by donors, the essences learned from experiences of Bangladesh and other programs would provide useful insights for promoting and disseminating PV technologies from the aspects of policy, program design for institutional arrangements, technology and O&M in the future.

In addition to rural electrification, installation of PV systems in public facilities such as clinics, schools, *etc*. in offgrid areas has been conducted.

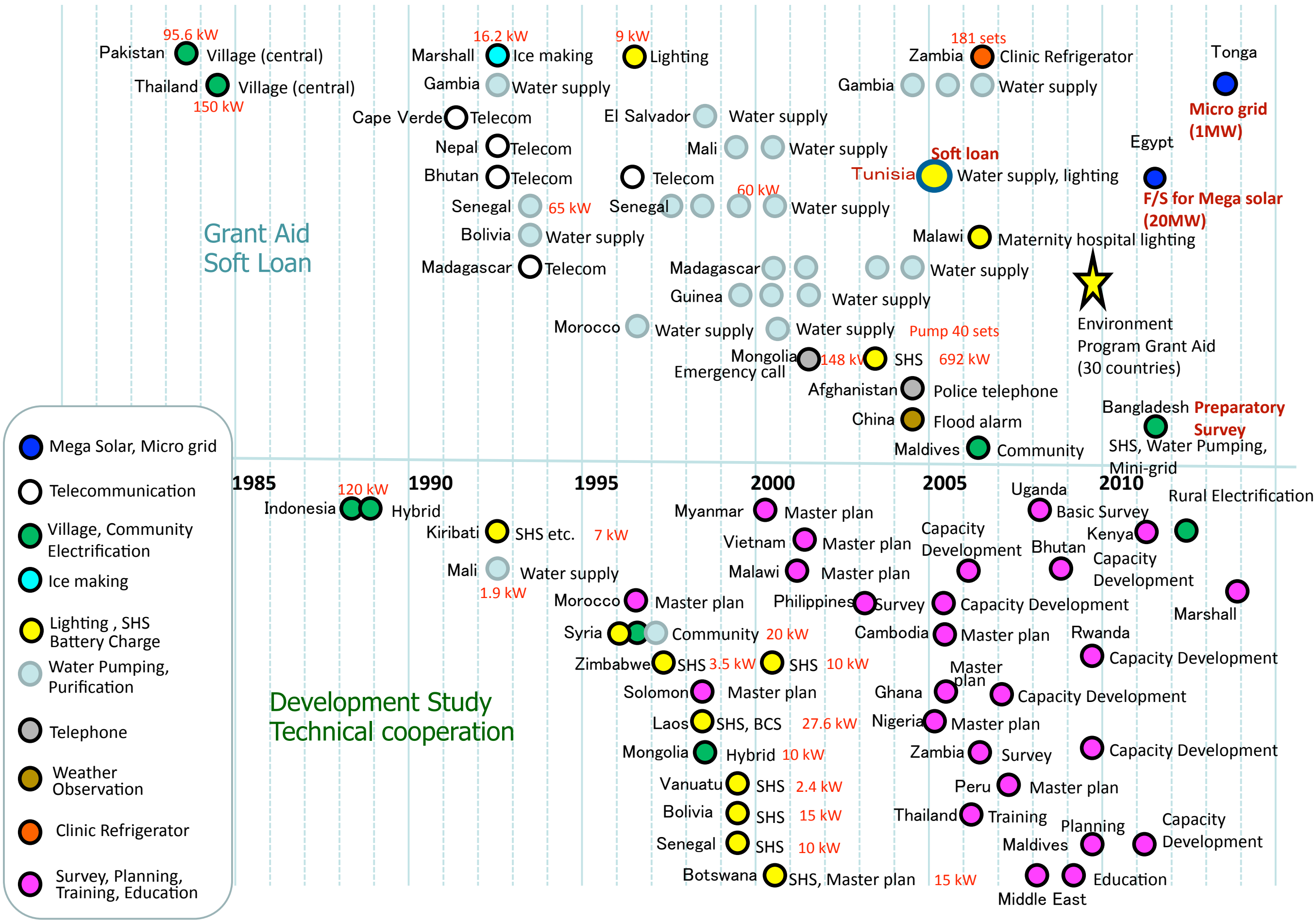


Figure 12: JICA's Historical Cooperation for PV (Technical and Financial)[1]

JICA also experienced many situations which did not lead to sustainable operation, including that of Pakistan in the early 1980s. The cases include systems being given up due to realization of grid connection; community-based BCSs without operation caused by unclear responsibility for operation; and programs not properly taken over by the successors.

On the other hand, there were some *graduated* programs that completed 100% penetration of SHSs for potential

> *Lesson Learned 2*
>
> PV programs, as a whole and individually, require the existence and sustainability of experienced personel with responsibility and enthusiasm

users, such as the Mongolian 100,000 solar yurt program for nomads, to which Japan provided a grant aid to complete 30% as an initial stage.

It is concluded that off-grid PV technology promotion programs should be integrated with national level electrification master plans and policies. The programs also require sustainable human resources with technical knowledge, responsibility, and enthusiasm.

On the other hand, JICA has been introducing several grant-based on-grid PV systems, typically several hundreds of kW_p, in around 30 countries to date for the development of the renewable PV systems after connection to the grid. So-called mega-solar has now come into the scope for support.

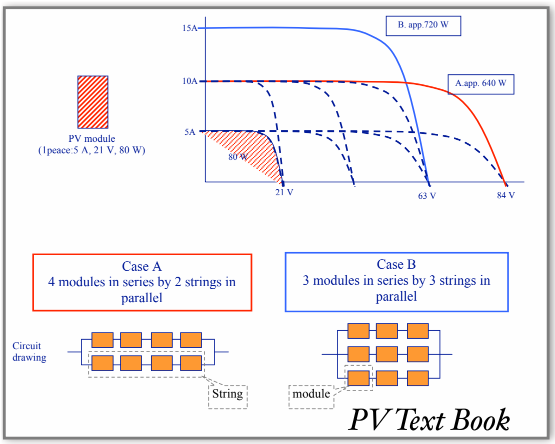
In Tonga, a 2.3 MW_p grant-based PV system (of which JICA's portion is 1 MW_p) will be integrated into the roughly 10MW system by diesel gensets. JICA is introducing equipment for stability of the power supply, since PV output fluctuates considerably. Since Japan is keen on technological solutions to solve the problem of the *quality* of electricity, this type of cooperation is expected to provide new channels for remote areas with stand-alone diesel systems, such as small island states, to increase the portion of indigenous renewables and reduce the cost of diesel fuel.

IV-2. JICA's Lessons Learned

IV-2-1. Capacity Development

IV-2-1-1. Lessons Learned

JICA's support includes intensive capacity development programs regardless of the capacity of Solar Home System (SHS) in 20 W_p to on-grid systems in MW_p or more. In order to meet proper design, components, installation, operation and maintenance, the stakeholders need a thorough understanding of the nature of the PV system. Among the experiences of both JICA and other organizations, there are dozens of examples of operations which did not achieve sustainability due to failure on this point.



Source: JICA Technical Cooperation Project in the Philippines

For this, JICA has conducted many seminars both in Japan and on sites. In addition, JICA has also experienced capacity development programs in the form of South-South cooperation through development of a textbook that has broad utility and has been adapted to the realities of developing countries.

It has been confirmed that these efforts of horizontal dissemination are favored in most developing countries. In particular, the Philippine program textbook and trainees have been actively utilized for training programs in African nations.

Lesson Learned 3

PV technologies are not as simple as often expected. Without proper design, components, installation, and operation & maintenance, the system will fail or suffer damage

In addition to specific PV technologies, support for electrification policy-making in terms of Master Plan formulation, having gone through the processes of working and thinking together with local counterparts, have made a linkage for future action even if the plans and programs are not implemented at that time.

IV-2-1-2. To Bhutan from Japan – via Philippines

JICA's PV support program has revealed that the human resources and capacity of PV technology are the principal bottleneck of the successful implementation of the SHS (and other PV) programs. The following is an example of good practice in such a capacity development/ training program:

When Filipino engineers underwent JICA training to help create a SHS to generate electricity to remote areas of the Philippines, it was probably not envisaged that the results would extend as far away as the mountainous Himalayan Kingdom of Bhutan.

But since October 2009, three Filipino 'graduate' instructors have in turn trained a group of Bhutanese engineers on the establishment of so-called solar home systems, a simple and efficient method employing small solar panels and batteries which can provide isolated communities with a local power supply.

The program underscores the importance of south-south cooperation—developing countries helping each other—and the increasing centrality of triangular cooperation. Traditional donor countries such as Japan support the activity by teaming with experts from emerging nations to help other countries.

JICA has provided Bhutan with technical and financial assistance for several years to try to provide electricity to the small population of 700,000 by 2013. But because of its mountainous terrain, with little agricultural land or natural water supplies, penetration has only reached 40% in some rural areas.

Lesson Learned 4

Capacity development program of the South-South Cooperation are effective for both trainers and trainees through the mutual learning process. They also induce a cascade effect.

One solution was the establishment of localized solar home systems and since the agency had only recently trained a group of Filipino engineers in this same system, it was decided they might be best placed to train the Bhutanese. Courses were held in 2009 and 2010.

Bhutanese officials were initially skeptical, believing that instructors from Japan itself or other advanced nations were necessary, but both countries now believe the experiment has been successful.

Figure 13: Filipino Expert Trains Bhutan Engineers

"Without the commitment of the Filipino experts we would not have achieved such a good result," one Bhutanese official said, while the instructors said they had also learned lessons during the training which they could apply in the Philippines.

The newly-trained Bhutanese engineers will now train other local officials in solar power, in a so-called 'cascade effect' whereby a large group of officials will eventually receive training from an ever expanding group of instructors.

Figure 14: Capacity Development Program for Bhutan with Philippines and Japan

These experiences of capacity development programs are now continuing and elaborated further in the "BRIGHT" capacity development project at Jomo Kenyatta University of Agriculture and Technology in Kenya. It is expected that the University will be a hub of PV technologies in Africa and other developing countries.

Lesson Learned 5

User awareness campaigns should be user-friendly reflecting local situations such as capacity and literacy.

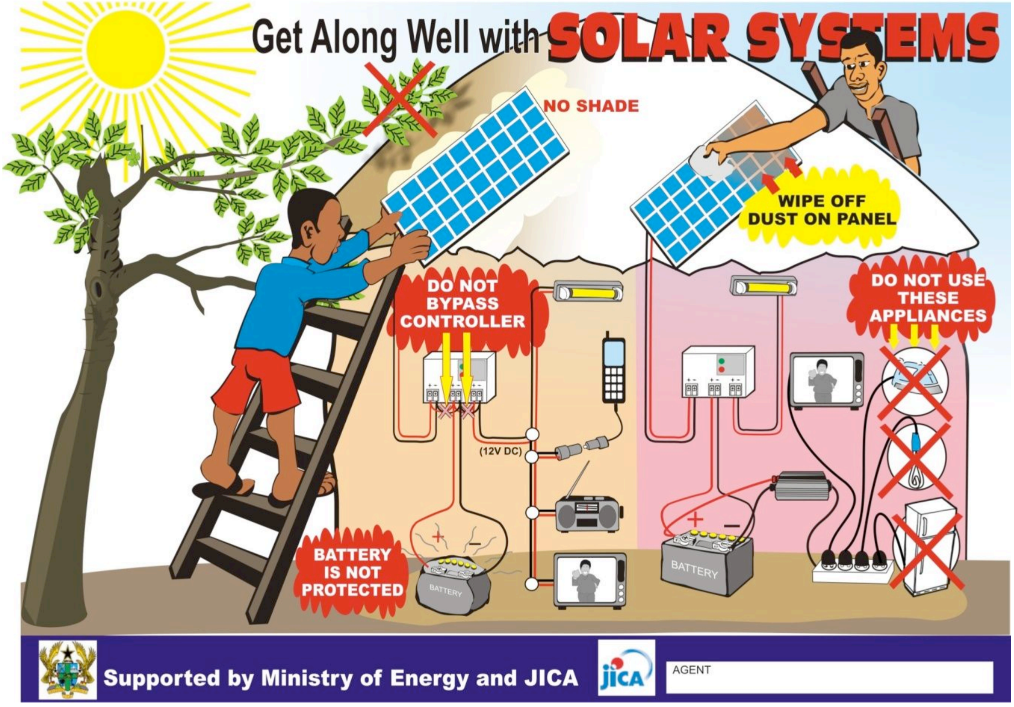


Figure 15: User Educational Material (Ghana)

Figure 16: “BRIGHT” Capacity Development Program in Kenya

IV-2-2. Functionable Management System for SHS

IV-2-2-1. Lessons Learned

Regarding governmental programs of promoting off-grid stand-alone systems such as SHS promotion programs, program design is seen as a key factor. In particular, the “program management system” is very important.

Management systems to be integrated with PDCA-cycled KAIZEN processes have functioned very well in the Bangladesh SHS program, the most expanding program so far.

Necessary factors include a design that unifies management of finance and installation with maintenance of SHS and associated capacity of the management team. As one of the functions of the management system, standardization of technical services including maintenance and quality management is also very important.

Although “pico solar” ($\leq 10W_p$) technologies seem to be a mainstream for individual households in the near future for lighting, reconsideration of SHS (around $50W_p$) is also desirable with the growing demand for TV and other appliances.

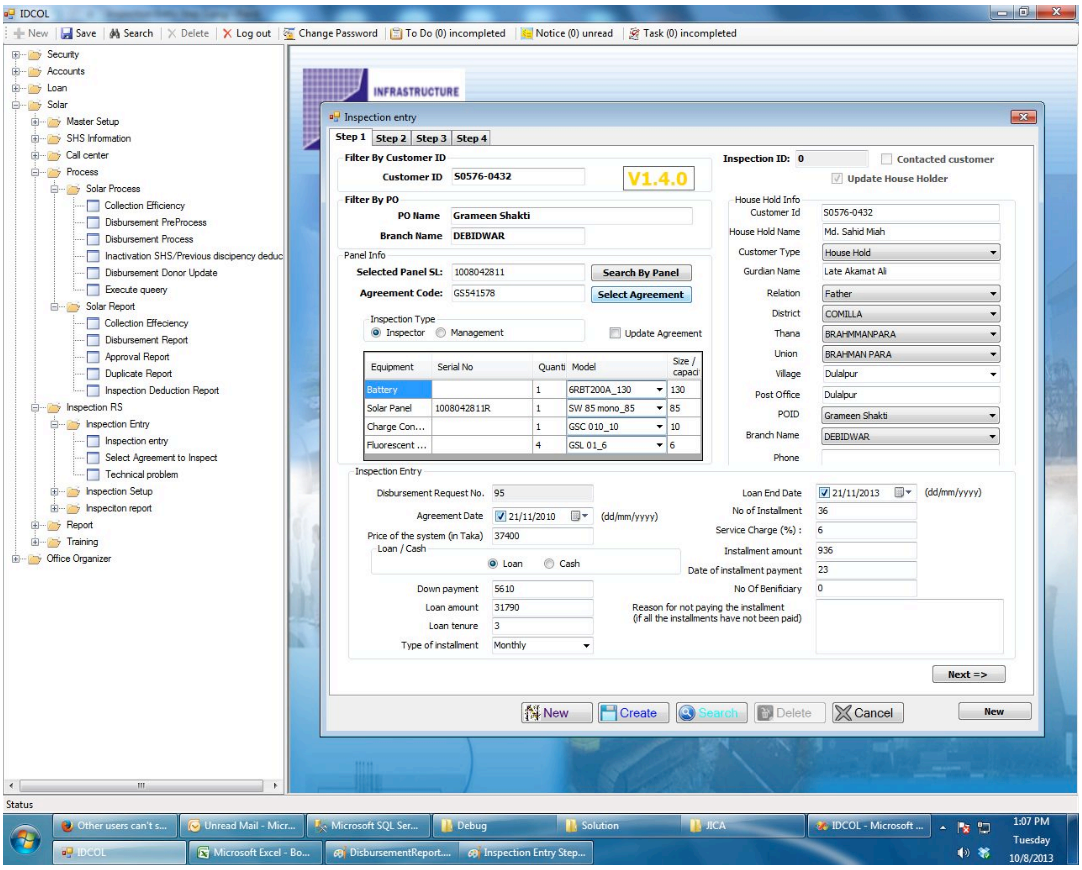


Figure 17: A Snapshot of IDCOL’s SHS Management System Software

IV-2-2-2. Summary of Essence [From the experiences of the Bangladesh Program]

From the experiences of the SHS programs in which JICA has been involved, the most expanding story of the Bangladesh program and other stories, it is concluded that the following points are key for disseminating SHS successfully:

Program Management System Design for Massive Installation of SHSs

Introduction capacity on the order of 10,000 SHSs per month requires a management system that takes into consideration the scale from the beginning in its design. It calls for a management system in which the Program Supervisor is able to grasp the status quo through monthly-updated database that includes information on SHS owner/user households, their loan repayment status, and operation and maintenance conditions of SHSs. The Program Supervisor must also be able to evaluate the program on a regular basis and make adjustments as needs arise.

> *Lesson Learned 6*
>
> Design the management system and database of the SHS program by backcasting from the target. Consider what information should be managed by the supervisory body.

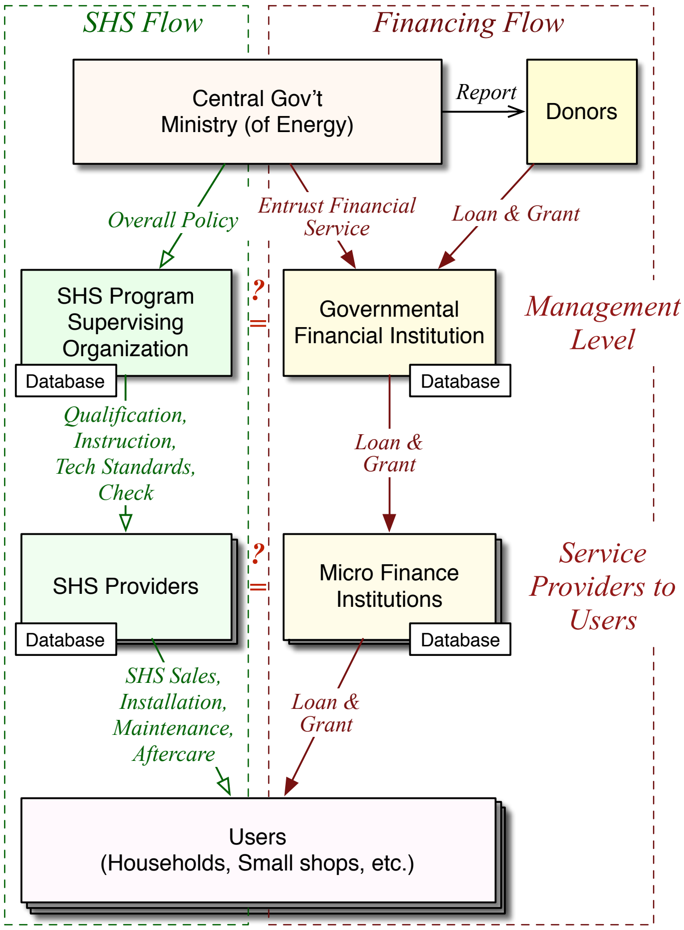


Figure 18: Two Fundamental Flows of a SHS Program

Program Structure Linking SHS Installation and Financial Service

It is preferable that an identical provider be responsible for both financial flow and system installations, if possible. That is, SHS providers can offer micro credit loan services (or providers can grasp household information through close cooperation with the agencies who provide financial services) under the uniform management of the Program Supervisor. Integration between loan collection and maintenance check (simple check) is desirable.

> *Lesson Learned 7*
>
> Enable SHS providers to provide financial services ensuring uniform management of information and integration of loan collection with maintenance check.

Capacity/Ability of Program Supervisors and SHS Providers

It is desirable that the Program Supervisor be responsible for the whole management system and that SHS providers take care of 'subsets' under the system (*esp*., databases). The Program Supervisor and SHS providers are required to have corresponding capacities to take responsibility for managing the system. Moreover, the Program Supervisor should set up necessary qualifications for the providers.

Systematic Professional Development/Technicians Training Systems

Installation of SHSs and provision of maintenance services need qualified technicians in large numbers in addition to development of manuals. Therefore, it is necessary to have a systematic technician development program. Lack of sufficient qualified technicians is seen as an obstacle for both program expansion and system reliability in most countries.

> *Lesson Learned 8*
>
> Systematic capacity bulding and training programs for technicians and users are necessary. Frequency may be determined based on backcasting from target numbers.

Creation of Incentives and Competitive Environment for Providers

Since most SHS providers are private agencies, in order to install SHSs efficiently, as many as possible and to conduct management in a proper fashion; it is preferable to introduce some incentives for them (creating competitive environment through allowing leeway) into the program. For this, it is important to take into consideration providers' business models and their time evolution during the program design.

> *Lesson Learned 9*
>
> Enable SHS providers to make a discretionary decision of business for competition. Loan services will yield profits and piecework incentive scheme is useful.

Demand-side Management

To ensure users' proper application of the systems, it is preferable to give instructions on proper methods of application to users and regularly check their operation of the systems. At the same time, it is desirable to control and understand households' electricity demand appliances and their usages so that demand cannot overrun the supply capacities of systems. Particularly, if users apply alternating current (AC) equipment by use of inverters in their own way. Improper inverter use could shorten the lifetime of batteries by overloading the batteries through excess demand beyond what the system can supply.

Technology Standards and Warranties

> *Lesson Learned 10*
>
> Introduce certification and quality control systems for equipment in order to mitigate risks on users.

From the perspective of exercising providers' self-initiatives and creating a competitive environment, it is desirable to have providers freely select equipment required for their SHS business. Therefore, for quality management of the equipment available, it is preferable for the Program Supervisor to establish technical committees (or assign some external organizations) and use only equipment approved thereby.

It is not necessary to satisfy all points mentioned above together. However, it is necessary to determine the requirements of a program at the initial stage though a backcasting approach based on target numbers and schedules.

At the least, it is essential that the Program Supervisor should have a management system that covers functions of monitoring, reporting and checking and self-adjusting (the so-called PDCA-cycle).

The well-working Bangladesh program is attributed to a sound program design by IDCOL based on the experiences of developing countries. From JICA's experience, the Vanuatu project reported the importance of clarification of ownership of PV systems for operation and responsibility for maintenance.

Toward a successful model for African nations, it is indispensable to utilize existing systems (administrative systems of local governments or sales/distribution networks of companies) that can reach end users in remote areas, as population density in African nations is very low. It is seen as possible to clear obstacles through a sales model (similar to the solar lantern model starting to scale up) with do-it-yourself level packaged technology. On the other hand, some measure is necessary to reduce the initial payment by the government or by the private companies.

From a number of beneficiaries, pico solar technologies may be the mainstream for the way forward. However, SHS can also play significant complementary roles providing corresponding system improvements.

IV-2-3. New Channel—Grid Connected Systems

IV-2-3-1. Lessons Learned

PV systems are a new valid way for dealing with issues of energy accessibility or rural electrification in off-grid remote areas and small island countries where diesel power generation has been the unique power source. JICA has also conducted several technical assistance and pilot projects on dispersed PV systems such as SHS and battery charging stations (BCS).

> *Lesson Learned 11*
>
> Various institutional arrangements are required for development of on-grid PV systems by removing barriers.

On the other hand, PV power generation bears a substantial concern about supply stability. Thereforethe the challenge is how to solve the problem and increase a penetration share of PV technology as well.

From 2008, JICA has supported installation of on-grid PV systems in around 30 countries; PV systems with capacities of several hundred kW_p have been installed and linked to grids without applying batteries. At the same time, a number of challenges have emerged and been resolved during the process. Guidelines for on-grid PV system technology were also developed in some cases.

For many countries, these were the first trials of such an on-grid system. Considerable obstacles from institutional issues and technical problems, including how to deal with the reverse power flow, have been cleared. It is expected that in the near future private companies can start their businesses smoothly in these countries.

Moreover, they are intended as demonstration projects which aim to disseminate renewable energy as a countermeasure to strengthen energy security and mitigation of climate change. In order to raise the awareness of the general public and academia, the bearers of countries' futures, the PV systems have been installed in plain view at airports and universities among other locations.

IV-2-2-1. Grant Aid Specific to Environment Purposes

So far, Japan has actively supported developing countries that are making efforts to tackle climate change and those that are vulnerable to climate change. Among the $30 billion climate finance commitments from developed countries in 2010–2012, Japan's share is $17.6 billion (14 billion out of public funds). In 2013–2015, Japan has mobilized 16 billion dollars as its commitment.

As a forerunning approach, in order to support adaption and mitigation policies in developing countries, a new environmental program grant aid was launched in fiscal year 2008. As a response, the Ministry of Foreign Affairs of Japan has conducted surveys to understand concrete needs from developing countries and has received requests from many countries on the needs for renewable energy technologies, especially for PV power generation technology.

The key principle of the program is emphasizing showcase effects, utilization of competitive Japanese technologies and know-how, and establishing sustainable management and maintenance systems. As per the principle, it has been decided to apply on-grid systems without batteries—rather than stand-alone systems for off-grid electrification—in metropolitan areas; government buildings, airports, hospitals, universities and other public facilities have been selected for the installation of PV systems with capacities of several hundreds kW_p. Together with procurement and installation of PV systems, technical support has taken place for formulating maintenance systems, including human resource development.

By taking this approach, a substantial leapfrogging development of PV technology is expected as on-grid PV technologies and mini grids can be utilized even in developing countries that need grid expansion and small islands where diesel generation is seen as the only option, for the purpose of energy security and mitigation of climate change—different from electrifying poor off-grid villages.

Lesson Learned 12

Hybrid systems of PV and diesel are valid way for remote areas and small island countries where diesel power generation is inevitable.
Designs should be based on the demands such as power amount and quality.

Figure 19: Several Grid-Connected PV Systems by Japanese Grant

In the case of ongoing projects, implementations are going well, including the soft components of technology transfer. Projects that have been handed over to host countries are being operated well under the local management and maintenance systems alone. It is confirmed that JICA’s support for human resource development has worked in favor of the capacity building of local technicians, which in turn supports normal operation of projects without relying on the assistance of Japan.

In 80% of the target countries, the projects are seen as the first of their kind and have played a pioneering role in the introduction of PV power generation to their domestic power network. Environmental arrangements such as technology transfers and guidelines development are completed through JICA's projects. If cost competitiveness of the technologies is cleared, broad promotion of renewable energy in these countries can be expected.

The systems in the program are especially effective for small island countries, which are forced to rely heavily on expensive diesel power generation. The program targets small island countries such as Maldives, Micronesia, Palau, Marshall Islands and Tonga.

IV-3. The Way Forward

JICA is one of the pioneers of promoting PV power generation technology to developing countries. Having started with dispersed off-grid type technology, it takes the initiative in the promotion of on-grid PV systems.

It is worth sharing the experience and knowledge accumulated so far with international communities and new development partners (including private companies, NGOs, civic communities and universities). In addition, as a next step, JICA intends to shift its efforts to highly challenging areas such as responses to system instability associated with mass introduction of the solar systems into the grid and contributing to the world through exerting Japan's technologies.

Figure 20: Image of Smart Micro-Grid System in Tonga by Japanese Grant