OFF-GRID PHOTOVOLTAIC APPLICATIONS IN INDONESIA: A FRAMEWORK FOR ANALYSIS

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Abstract

This paper introduces a study on the sustainability of off-grid photovoltaic (PV) applications in Indonesia. Since the 1980s, approximately 5 MWp of PV power has been installed in the remote parts of various Indonesian provinces. Despite the number of PV power installations significant questions concerning social, economic, institutional, technical and environmental dimensions remain as to how they can contribute to the sustainability of the lives of rural Indonesians who do not have access to grid electricity. In this study, these dimensions will be explored in relation to off-grid electricity supply by analysing how villagers and islanders might harvest benefits from the implementation of PV in off-grid applications.

1. INTRODUCTION

The fragmented geography of the Indonesian archipelago together with an uneven population distribution has created problems extending the nation's power grid. Off-grid photovoltaic (PV) systems are therefore considered a solution for remote area electrification and a number of photovoltaic rural projects have been in operation in Indonesia since 1989. Approximately 5 MWp[1] of PV power has been generated from various PV applications implemented to date (including PV for water pumping, communication, health care, etc.) of which Solar Home Systems (SHSs) alone have contributed 1.8 MWp [2].

Villagers have responded positively to the PV installations and have acknowledged an improvement in their quality of life (see for example [3]). However has PV provided 'raw fish' into the hands of the villagers or has it provided the 'fishing tackle' for them to 'fish' and improve their lives? The questions that arise therefore are:

1) In what ways has PV improved the life of rural Indonesian people?
2) Can PV become a tool for rural development making rural life more attractive?
3) Have all the potential applications of PV that may deliver service to rural people been identified and implemented?

The primary objective of this research project is to study how PV can contribute to the sustainability of the lives of rural Indonesians who do not have access to grid electricity, by considering the social, economic, institutional, technical and environmental dimensions of PV projects. These dimensions will be explored in relation to off-grid electricity supply by analysing how villagers and islanders, and on a larger scale present and future generations, might harvest benefits from the implementation of PV in off-grid applications. This is intended to scope a potentially broader study focused on the use of PV as a means of rural energy development by, for example, facilitating income generation and broader improvements in social welfare.

1.1. Socio-Economic Aspects

The author intends to study the acceptance and perception of PV and the social and economic development to which it has contributed. Despite the number of PV systems installed across Indonesia, many questions remain regarding matters of socio-economic development. This includes lifestyles, education, economic activities and the facilitation of social activities at night, which can all potentially add value and create benefits making village life

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more attractive and thus reduce migration to urban settlements.

Villagers can purchase SHSs through a revolving fund scheme that is supported by either government or donor assistance. This fund is administered by the village cooperatives unit *Koperasi Unit Desa* (KUD). The financial sustainability of these systems can be assessed from answers to the following questions:

1) Is the current direction of PV investment economically sustainable?
2) Does PV contribute to improving the economic performance of rural communities?

Of the 210 million people living in Indonesia in 1999, 95 million lived in rural areas [4]. These rural inhabitants are generally farmers, artisans, craftsmen, fishermen or small-scale traders. Many occupation-related questions arise here such as:

3) Has PV helped households to generate income from their business activities?
4) What PV designs are best suited to facilitate the local economy (eg. agricultural and off-farm productive activities)?

1.2. Technological Aspects

PV being a newly introduced technology could entail a cultural gap between system designs and user requirements. Thus it is important to assess the technological sustainability of PV suggesting questions such as:

1) How have villagers dealt with maintenance of PV systems, system failures and wastes such as electronic components, cables, batteries and lamp tubes?
2) Have there been any user innovations aimed at either enhancing the system's capacity, adopting them for changed uses, or repairing failures?

1.3. Institutional Capacity

Rural PV projects involve many institutional stakeholders, including government agencies (cooperatives, transmigration, technology development, planning, energy, and banking)[2], sponsoring bodies/donor[3], and local communities. As an example, figure 1 illustrates the network operation of the "50 MWp One Million Roof" rural electrification program. The diagram shows both the program and fund flows of the project agreements, their operation and monitored activities.

Many questions about institutional capacity arise from the operation of this network of stakeholders:

1) Is this the best form of cooperation and does it work effectively?
2) Is this institutional framework sustainable?
3) What should be the role of each body in each phase of decision making, project implementation, post-project monitoring, PV training, education and dissemination?

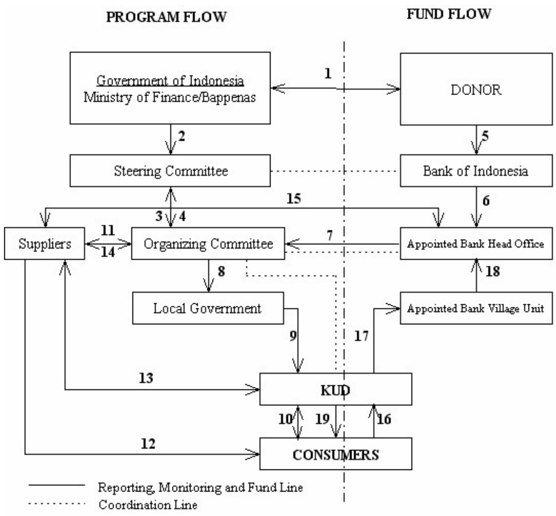

Figure 1. Organizational structure of PV rural electrification project [5].

Legend: 1 - Loan agreement. 2,3,4,8,9 - Program coordination from government to localities. 10,11,12,13,14,19 - Contract arrangement. 5,6,7,16,17,18 - Fund flow. Source: [5].

KUD is a key institution whose role is to oversee the administration of the projects at the village level, collecting PV payments and providing spare parts and a maintenance service. Several questions arise from this:

4) Does KUD have sufficient management capacity and resources to play this central role?
5) Are there appropriate regulations and penalty mechanisms to ensure timely collection of payments?

1.4. Environmental Aspects

The PV systems supply villagers with electricity for powering lighting, black and white TVs, radios and for telecommunications. Before the introduction of SHS, the villagers used fossil fuel sourced energy such as kerosene for lighting, dry-cell batteries for radios and automotive batteries for TVs. In some places diesel engines are used to meet the energy

[2] The governmental agencies include BPPT (the Agency for the Assessment and Application of Technology), MOC (Ministry of Cooperatives), Ministry of Transmigration, DGEEU (Directorate General for Electricity and Energy Utilization), Bank of Indonesia.
[3] For instance E-7, GEF, World Bank, USAID, AusAID.

needs of community gatherings. In order to examine the environmental sustainability of these applications, we need to answer the following questions:

1) From the perspective of the replacement of fossil fuels: how much are CO_2 emissions and other environmental impacts reduced?
2) In dealing with PV system wastes such as electronic components, cables, batteries or lamp tubes: has waste management at the local level been adequately facilitated?

2. PROJECT DESCRIPTION AND METHODOLOGY

The project is a combination of both social and engineering research that is intended primarily to examine the sustainability of PV systems as a means of rural electrification. For the social aspect, it is intended to study how villagers and islanders can use PV as a development tool rather than merely a new technology.

The methodology of the project will include literature research, field research in villages where PV systems have been installed, and interviews with key stakeholders. The field research is intended to investigate villager expectations and their degree of satisfaction, PV system performance, experience with the maintenance of PV systems, experience with the failure and replacement of PV systems, and monitoring protocols. The interviews will be used to identify the costs, benefits, and values associated with the PV system as well as a potential alternative flexible PV design able to be more easily reconfigured by users to meet their requirements.

3. CURRENT PROGRESS IN FINDINGS

3.1. PV Installations

To date approximately 5 MWp of PV power has been installed in the various provinces for powering lighting, water pumping, ice making, desalination, communications, health care, etc. Of the 5 MWp SHS contributed 1.8 MWp. Typically, a SHS is rated at 45-50 Wp and generates 240 Wh/day under an average solar irradiation of 5kWh/m^2/day [6].

The first experimental pilot programme was the installation of 102 SHSs in the village of Sukatani, West Java in 1988 [6]. Subsequent to this 500 SHSs were installed in the Cileles village, Lebak district in West Java in 1991 [7]. Since 1991 the BANPRES (Presidential Aid) programme has installed 3,300 SHSs in 13 provinces of Indonesia [2]. In 1997 the Government of Indonesia (GOI) set up a programme to install one million SHS (50 MWp) nationwide by 2005. To participate in GOI's "50 MWp One Million Roof" program, AusAID assisted GOI to install 36,400 SHSs in nine eastern Indonesian provinces during the period 1997-1999, the World Bank and the Global Environment Facility (GEF) assisted the GOI to install 200.000[4] SHSs in Lampung (Sumatra), West Java and South Sulawesi, while the Bavarian-Indonesian BIG-SOL[5] project has installed 90 units of PV systems in East Java since 1997 mainly for chicken barns, egg hatching, rural telephone and radio and lighting for fishing boats [8].

3.2. Financing Scheme

For the purposes of financing, it has proved useful in Indonesia to classify potential users into three segments in accordance with their economic standing: 1) Under developed; 2) More developed and 3) Developed economic standing [5], see table 1. This classification is utilized to define the level of financial assistance required and hence the payment scenario.

Table 1. Market segment and financing scheme.

Segment	Responsible Authority	Financing Scheme	
		What GOI paid	What Consumer paid
1. Under developed economic standing. This includes the under developed villages and transmigration sites.	DGEED, Department of Transmigration, Dept. of Internal Affairs, Dept. of Health, Local Government.	Tax, PV system, installation and transportation fees, site surveys, training to operators and consumers.	Monthly maintenance fee for operational cost and saving on battery replacement.
2. More developed economic standing with ability to pay and grid electricity will likely to arrive within 5-10 years time.	BPPT, Dept. of Cooperatives.	Installation and transportation fees, site surveys, training to operators and consumers, interest.	PV system through lease-purchase contract, down payment and monthly payment for a period of 10 years.
3. Developed economic standing with willingness and ability to pay and grid electricity will likely to arrive within 3-5 years time.	PV Dealers and Distributors.	Subsidies of a fraction of whole system price provided by donor.	PV system through lease-purchase contract, down payment and monthly payment up to 3 years.

Source: Extracted from [5].

Segments 1 and 2 are demonstration schemes while segment 3 is a semi-commercial scheme. Most SHS systems implemented have been operated under segments 1 and 2 schemes (eg. Banpres, AusAID and BIG-SOL projects) whereby the end-users pay instalments for up to a 10 year period. The projects with World Bank/GEF financing have been operated under a segment 3 scheme whereby customers pay a larger down payment with a shorter period of instalment (up to 3 year period at the maximum).

[4] This figure has been retargeted at 70,000 units by the year 2001 due to the currency depreciation as a result of the economic crisis that hit Indonesia in the late 1997 [11].
[5] The Bavarian-Indonesian Government Solar Project.

The experimental pilot project at Sukatani was well monitored with regular site audits of technical and social aspects of the project [9]. The SHS users at Sukatani have continued to express a positive response toward SHS even fifteen years after its initial installation. When grid electricity arrived at Sukatani in 2001, the users kept the PV system for back up power when the grid fails [10]. When comparing Sukatani, a model PV village, with others, the question as to how similar the outcomes will be elsewhere in Indonesia, particularly in regard to project management, monitoring and the impact that PV has had on the local community arises.

3.3. PV Commercialization

Many PV dealers and distributors have been active, primarily through governmental project, since the inception of PV in Indonesia. In response to the presence of a third segment of consumers, PV dealers play an active role in this framework including identifying potential and eligible customers and determining their payment terms. The payments have sometimes been very flexible particularly for customers with irregular/seasonal income streams.

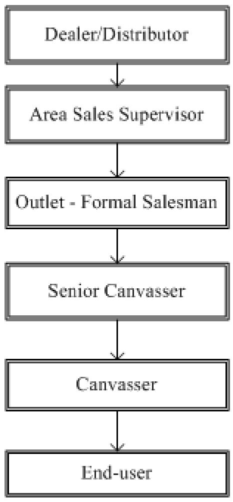

Figure 2. A typical PV sales structure.

Figure 2 shows an example of a sales structure where PV systems are delivered from the distributor to the end-users through a chain of Area Sales, Outlet, Senior Canvasser, and Canvasser at the local level. To encourage the commercialisation of a SHS market the World Bank and GEF have provided subsidies to the amount of US$ 2/Wp since 1997 [11].

There are a number of issues relating to this level of subsidy and the way it is spent:

Have the subsidy schemes covered the market development activities? Or is further assistance required?

It should be noted that PV reaches the consumers through a chain of agents and over large distances which incurs significant operational costs for site surveys, installation and transportation fees, and also for training of operators and consumers. In comparison these cost are paid by the government in segment 1 and 2 schemes [5].

Other issues of interest include the availability of consequences arising from the after sales structure and the protocols used to ensure consumer satisfaction.

3.4. Domestic PV Industry

Apart from the solar module all SHS equipment is produced domestically. Industries that provide the Balance of System components (lamp tubes and luminaries, electronic controller, battery etc.) exist in Jakarta and Bandung (West Java). In addition to BOS manufacturing, a local industry of module assembly also exists in Bandung. While this demonstrates active local industry involvement, it has yet to be proved that these activities directly alleviate poverty.

3.5. PV Second Hand Market

There is an interesting phenomena in the emergence of a second hand PV market in some parts of Lampung, Sumatra. The presence of a second hand market demonstrates a growing willingness to pay for PV systems in rural communities and raises interesting questions as to whether local innovation in the use of PV is occurring that could be further facilitated. Other questions that arise with the advent of this market concerns the value of the PV systems and the implications of the presence of the market such as: why are owners selling their PV systems (which could encompass technical or financial difficulties) and why are others willing to buy second hand systems when the quality and warranty may be questionable. This market may have both positive and negative implications worthy of further investigation such as matters of theft, reparability, spare component availability and the labour required for repair.

4. FUTURE PLAN

In the substantive research phase the current findings will be utilised to construct a survey design and other research methodologies and nominate villages to be surveyed. A broad spectrum of stakeholders will be interviewed, including users (villagers and islanders), manufacturers and representatives of the institutional bodies. The latter will include KUDs, governmental agencies, and local government. Villagers from different geographical areas will also be studied.

5. SUMMARY

Approximately 5 MWp of PV power has been installed in Indonesia involving many agencies. The PV industry has been actively involved in these PV projects both through government initiated activities and in PV commercialization more directly. However significant questions concerning social, economic, institutional, technical and environmental dimensions remain as to how PV can contribute to the sustainability of rural Indonesians who do not have access to grid electricity. The author intends to study the acceptance and perception of PV and the social and economic development to which it has contributed. The current findings will be utilised to further construct a survey design and other research methodologies as well as nominating villages to be surveyed in the ensuing substantive research phase. A broad spectrum of stakeholders will be interviewed to explore the sustainability questions of PV in off-grid applications, and how villagers and islanders might harvest benefits from these systems.

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