

Off-Grid Photovoltaic Applications in Indonesia: An Assessment of Current Experience

M. Retnanestri¹, H. Outhred, S. Healy

The University of New South Wales

UNSW Sydney 2052 – AUSTRALIA

Phone: +61 2 93855157, Fax: +61 2 93855993

E-mail: m.retnanestri@student.unsw.edu.au

h.outhred@unsw.edu.au ; s.healy@unsw.edu.au

Abstract – *This paper reports interim findings of a research project that is investigating the sustainability of off-grid Photovoltaic-based Energy Conversion Systems (PVEC) in Indonesia. The general question of this research project is how can PVEC contribute to improving the sustainability of the rural Indonesian communities without access to electricity grid? This study was first introduced at the ANZSES Conference in 2003 where results of the preliminary fieldwork undertaken in late 2002 and early 2003 were presented (Retnanestri et al, 2003). As a follow up to that preliminary fieldwork, more substantive fieldwork was carried out in early 2005. While the preliminary fieldwork identified key issues used to construct the analytical framework for this project, the substantive fieldwork was used to collect more extensive data for analysis. An analytical framework was constructed to investigate to what extent the existing PVEC delivery models address issues of the institutional, socioeconomic, technological and environmental dimensions of sustainability. A broad spectrum of PVEC stakeholders involved in PVEC project operation, including manufacturers, distributors, research agencies and end users were interviewed to understand the extent to which some specific PVEC projects had addressed PVEC sustainability requirements. This included an assessment of the costs, benefits, and values associated with the role of PVEC in fulfilling rural energy needs, its potential role in facilitating sustainable rural development (SRD) and national development at large. Some case studies resulting from the substantive fieldwork are presented and analyzed by using the analytical framework developed for this purpose.*

1. INTRODUCTION

The 1980's witnessed the development of worldwide enthusiasm for PVEC. Hankins (in Krause and Nordstrom, 2004) identified three factors attributable to this; a PVEC price drop in the late 1980s, the success of demonstration projects and the invention of solar home systems (SHS). As of 2002, 78% of the total 66,215 Indonesian villages have been electrified (PLN, 2003). However, until 2003, only 53% (PLN, 2004) of households have actually been electrified leaving approximately 26.5 million Indonesian families without electricity. The fragmented geography of the Indonesian archipelago together with an uneven population distribution creates difficulties for extending the nation's power grid. Off-grid PVEC is therefore considered a solution for remote area electrification and a number of PVEC projects have operated in Indonesia since the 1980s. The Indonesian situation is not unique and runs parallel to that in other developing countries such as the Philippines, Sri Lanka and many in Latin America, which also received donor support under bilateral agreements (Krause and Nordstrom, 2004). To date approximately 28 MWp (IEA, 2004) of PVEC power has been installed across Indonesia in various residential and public applications including lighting, water pumping, communication, health care, etc.

The findings from our preliminary and substantive fieldwork suggest that in some instances, villagers have responded positively to the introduction of off-grid PVEC in Indonesia (Retnanestri et al, 2003):

- PVEC installation has involved the establishment of local electricity cooperatives/management, which is a measure of the strengthening of local institutional capacity;
- PVEC systems have been used for supporting income-generating activities, which is a measure of the acceptance of PVEC into rural life;
- PVEC systems have been retained as back up power after grid connection, which is a measure of user satisfaction with PVEC reliability;

¹ On-leave from the Electrical Engineering Department, STTNAS College, Jogjakarta, Indonesia.

- PVEC users are willing to invest in larger systems, which is a measure of user's enthusiasm;
- Some revolving funds have been generated from past government projects, which is a measure of financial sustainability.

However, despite the massive number of PVEC installations and the considerable support provided and initiatives taken by donors and the government, to date the PVEC market remains well below its technical potential, which is projected to be 900 MWp (IEA, 1999). Many technical, cultural, institutional and economic problems have been identified from PVEC experience in developing countries. These problems are a function of system designs poorly matched to user needs, poor installation practices, and inadequate supporting institutional infrastructure (Outhred et al, 2004). These matters, coupled with a lack of access to finance and the top down delivery characteristics, have led to early PVEC system failure and poor repayment (Cabraal et al, 1996; Fitriana, 2003) preventing wider PVEC acceptance.

It is imperative that PVEC is more than a technocratic solution that may be incompatible with local culture. Importantly, PVEC should be delivered to rural Indonesians in an institutional framework that accommodates the interests of all stakeholders. Important success factors were identified as adequate service infrastructure, flexibility in system sizing, appropriate modes of deployment and pricing, good design, including measures to enhance the life of batteries and other system components, and user empowerment, including education in appropriate use and maintenance practices (Outhred et al, 2004).

2. PROJECT DESCRIPTION AND METHODOLOGY

The research project discussed in this paper is a combination of social and engineering research, encompassing qualitative survey work. This research is intended primarily to examine the sustainability of PVEC as a means of rural electrification. The primary objective of the project is to investigate to what extent the existing PVEC delivery models (governmental, commercial, community-based) address the institutional, socioeconomic, technological and environmental dimensions of PVEC sustainability. In this study, these dimensions will be explored through the lenses of accessibility, availability, acceptability and implementational structure and environment of PVEC delivery, defined in Section 3 below. Earlier papers describe the institutional framework for off-grid PVEC applications in Indonesia (Retnanestri et al, 2003), discuss the outcomes of preliminary fieldwork undertaken in late 2002 and early 2003 (Retnanestri et al, 2003; Outhred et al, 2004), and propose the PVEC sustainability examination model (Retnanestri et al, 2005).



Figure 1. An interview with villagers in the NTT province, Eastern Indonesia, May 2005.

The methodology of the project includes literature research, field research in villages where PVEC has been installed, and interviews with key stakeholders. The field research, which included visits to governmental institutions, donor agencies, PVEC industries, NGOs and PVEC sites, was conducted to obtain first hand knowledge from case studies related to PVEC sustainability in Indonesia. The interviews have been used to understand the extent to which a PVEC project has addressed PVEC sustainability requirements, and to a larger extent the costs, benefits, and values associated with the role of PVEC in fulfilling rural energy needs, its potential role in facilitating sustainable rural development (SRD) and national development at large. The project's success can be observed from a number of indicators including PVEC longevity, repayment rate, increase in market demand and

expansion of service area coverage. Many villages were visited in Lampung (Sumatra Island), West Java and NTT (Eastern Indonesia) provinces. PVEC sites visited include Solar Home Systems (SHS), PV Water Pumping systems and a PV-Wind-Diesel Hybrid system. Also visited were Manufacturers, Distributors and Research Agencies located in Jakarta, Bandung and Jogjakarta. In summary, 77 End Users and 68 Facilitators (manufacturers, distributors, government, research agency and NGO representatives) were interviewed.

3. PROPOSED PVEC SUSTAINABILITY EXAMINATION MODEL

Figure 2 below shows a PVEC Sustainability model, denoted as the “Four Pillars of PVEC Sustainability”, developed as part of this project. This model was developed to show how the institutional, socioeconomic, technological and environmental issues of PVEC delivery are addressed by maintaining *accessibility*, *availability*, *acceptability*² and the viability of the *implementational structure and environment* of PVEC delivery. Many components are listed under each heading; see Figure 2, for examination purposes. Some of them will be elaborated below:

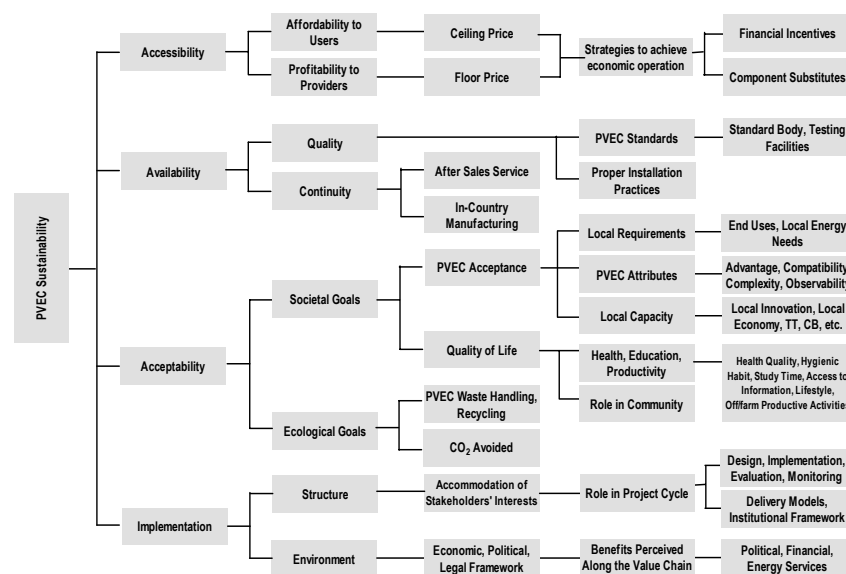


Figure 2. The proposed PVEC Sustainability examination model.

- **Accessibility** refers to the provision of reliable modern energy services at a sustainable price level (WEC, 1999), addressing financial and institutional issues of PVEC delivery. This component contains Affordability and Profitability which will be used to understand the gap between Floor Price and Ceiling Price, and the potential strategic measures (eg access for both providers and users to loan, credit, subsidy, grants, etc) required to assist the PVEC market to achieve economically viable operation. From the institutional perspective, accessibility can also mean, for instance, how local institutions can get access to outsourced PVEC projects.
- **Availability** covers quality and continuity of energy supply (WEC, 1999), addressing institutional and technological issues of PVEC delivery. It contains Quality and Continuity components used to understand the provision of technical standards, proper installation practices, after sales infrastructure and the existence of domestic manufacturing. Compliance to internationally recognized national PVEC Standards and Certification, and proper installation practices is a requirement to maintain product quality, competitiveness and customer guarantees. Together with in-country Manufacturing, National PVEC Standards and testing facilities are essential to maintain self-sufficiency.
- **Acceptability** covers both societal and ecological goals (WEC, 1999), addressing cultural, socioeconomic, institutional and technological capacity issues of PVEC delivery. PVEC Attributes include five characteristics of innovation diffusion: Relative Advantage, Compatibility, Complexity, Trialability and Observability (adopted from Rogers, 2003), which dictate users' acceptance. Relative Advantage is used to understand whether PVEC is perceived as “better than the idea it

² The terms Accessibility, Availability and Acceptability are the interlinked “three energy goals” as proposed by the WEC (1999). Owing to the respective coverage of the “three energy goals” and in combination with an implementational structure and the environment they fit well as a model of four pillars of PVEC sustainability.

supersedes” which is often expressed in terms of economic profitability, social prestige (status seeking), and other benefits (Rogers, 2003). Compatibility is used to understand whether PVEC is perceived as “being consistent with the existing values and needs” (Rogers, 2003) of the users. Complexity is used to understand the degree to which PVEC is perceived “difficult to understand and use”. Observability is used to understand whether PVEC’s results are “visible to others” (Rogers, 2003). In this study, these attributes will be used to understand how PVEC can potentially diffuse into local culture and whether local capacity exists to adopt PVEC and adapt, apply and develop it to better fit local conditions. The Ecological Goals component is used to understand the handling of PVEC waste as well as the benefits from avoidance of fossil fuel use (for instance CO₂ environmental benefits or cost saving from transportation for purchasing fuel).

- The **Implementation** issues of structure and environment assess to what extent the institutional, socio-economic, political, legal and administrative framework provides a facilitating environment for PVEC to operate sustainably, addressing institutional issues of PVEC delivery. They highlight the stakeholders’ roles in the project cycle and the benefits perceived along the value chain in relation to the flow of financial and PVEC energy services. PVEC Stakeholders include Sponsors (donors, governments, and PVEC manufacturers), Facilitators (research agencies, local government, PVEC distributors, banks, NGOs, village cooperatives) and End-users (individual, public)³. They relate in an institutional framework, which may be vertical (top-down/centralized), horizontal (decentralized) or Hybrid (combination of both) which may uniquely fit a particular situation (Rogers, 2003). In this study, the institutional framework of existing PVEC models will be studied and their respective performance will be compared. Implementational Environment looks at the socio-economic, political and legal environment in which PVEC is operating. A facilitating climate is required for PVEC to operate sustainably.

4. DISCUSSION: SUSTAINABILITY ISSUES IN THE OFF-GRID PVEC APPLICATIONS IN INDONESIA

4.1. Accessibility: Case Study 1 – Access to Financing

Financial and institutional instruments such as a strategic subsidy, business skill training and distribution infrastructure have been shown to give PVEC a good chance of success (Leitman, 2004). The World Bank/GEF project (implemented in Lampung, West Java and South Sulawesi) achieved a 95% credit repayment rate by providing these instruments in its project scheme, making PVEC more affordable to users⁴ and allowing providers to establish a distribution network in rural areas (Leitman, 2004). This case demonstrated the importance of access to finance making PVEC more accessible, hence affordable to users and profitable to providers.

The closure of the WB/GEF project in 2003, which provided a subsidy of \$2/Wp (PSG, 2003) for every SHS sold, restricted the distributor’s ability to provide credit for customers⁵. The distributor admitted that sales of SHS had decreased as they could only be sold by cash transaction and therefore only a limited number of wealthier farmers in the village could afford SHS at its current price level. SHS Distributors and Entrepreneurs, as well as many End Users, noted that if SHS could be marketed at 50 to 60% of its current price, SHS would have been affordable for more villagers. A case where a local outlet was forced to close down was found as a result of the WB/GEF project closure. In another case, a distributor made an approach to an overseas donor and an Indonesian bank to provide a new credit scheme. Bank Rakyat Indonesia (BRI), a governmental bank which has over 4,000 branches in the urban and rural areas, is willing to provide credit for 50 Wp SHS, with a flat interest rate of 18% per year over a 24 month period. Mambruk Corporation, assisted by Netherlands-based Triodos bank, with its Renewable Energy for Development Funds, has piloted this scheme with BRI bank for 24 months in Baturaja district, Sumatra Island. As no collateral is required from the Customer, Mambruk provided a “buy back” guarantee in the case of a customer default at which time the SHS would be repossessed. Although sounding promising, Mambruk representatives admitted that progress has been relatively slow. This is mainly due to the rural customers’ unfamiliarity in dealing with a banking system. This case indicates that even if there are partners to share the market risk, there are still challenges with local capacity when exposed to an ‘unconventional game’.

³ The stakeholder classification of Sponsors, Facilitators and End-users is equivalent to the terms Change Agency, Change Agent and Clients used in Rogers (2003).

⁴ However customers are limited to wealthier rural households (Leitmann, 2004).

⁵ Personal communication, April 2005.



Figure 3. (Left) A 50 Wp SHS, marketed under the WB/GEF project, installed on a hut roof of a fish floating net at Cirata dam, Jangari Village, West Java. (Right) A 50 Wp SHS installed by Womintra⁶ in front of a house in the village of Pusu, NTT, Eastern Indonesia Province. The WB/GEF semi-commercial project provided 20% of subsidy to villagers in Lampung, West Java and South Sulawesi. Remote societies in other parts of Eastern Indonesia, as depicted in the picture on the right, require a greater amount of subsidy to own PVEC.

The customers of an organic SHS market⁷ in Lampung, also in Sumatra Island, chose to purchase SHS without the Battery Charge Controller (BCR) in order to save approximately \$20. This decision was also based, in part, on the villagers' perception that having a controller also raised technical and psychological issues. This issue will be addressed further in the following sub-section. Representatives of two distributors argued that aside from the main purpose of protecting the battery, the BCR is also a significant part of the business. The competing interests, between technical purpose, 'politic' in the business and customers' freedom of choice need to be addressed cautiously.

4.2. Availability: Case Study 2 – the Significance of After Sales Infrastructure

In 1989, 102 PVEC lighting systems were installed in the village of Sukatani in West Java as a pilot PVEC village program. The project at Sukatani was monitored and periodic site audits of the technical and social aspects were conducted. The experimental project at Sukatani demonstrated good financial management and bookkeeping practices but that has not always been the case for other projects. An anecdotal report from another project mentioned that a new management board encountered difficulties continuing PVEC system service and management when taking over the role from the previous board because of an inadequate transfer of knowledge. This resulted in a lack of trained technicians and spare parts, eventually leading to non-payment by some users. As there were no penalties involved, non-payment became common among other users (Retnanestri et al, 2003).

In the Hangaruru and Kiritana villages, East Sumba, there are many homes that have SHS installed on their roofs but continue to use kerosene for illumination purposes as illustrated in Figure 4. The batteries installed during the AusAID project implementation in 1997/1999 had started to malfunction by 2001 forcing the majority of users to revert to kerosene lamps, while the remainder have replaced the batteries with new or second-hand ones. Many users noted that it was too expensive to buy replacement batteries. However, by calculation, assuming a battery has a life of three years, they actually spend more on kerosene during the same period. The fact that kerosene can be purchased on an ad hoc basis may have supported their decision. The AusAID project was originally designed to have village cooperatives already established at district level, "Koperasi Unit Desa" (KUD), to collect payment and provide after sales service. Monthly savings for battery replacement was also part of the monthly instalment. Fitriana (2003) reported that this monthly repayment only worked well in the first year. By the following year, End Users had stopped paying for various reasons such as the break down of BCR, lamps and batteries compounded by the poor availability of spare parts. The money collected by KUD was also used for other purposes such as buying a motorcycle (Fitriana, 2003) presumably deemed to be a necessity for mobility in the collection of monthly payment. The people in Hangaruru village admitted that they have stopped paying the instalment in the second or third year as no one came to collect the money. The villagers also have little idea as to whom they should talk to resolve the problem, as well as where to find spare parts.

⁶ A foundation based in Kupang, NTT, specializing itself in the rural community empowerment.

⁷ A private SHS market operated by local entrepreneurs, the systems sold include new and used modules.



Figure 4. (Left) A 50 Wp SHS module installed on a house roof in Hangaruru Village, East Sumba. This module is not operational, it is the petromax lamp shown on the inset which actually illuminates the house. (Middle) An old couple in Padasuka Village, Lampung, who have owned their SHS for 14 years, accompanied by their children who also have SHSs installed in their houses. (Right) SHS spare parts and consumables, along with the price list, displayed at the PLD office in Pusu Village, NTT Province.

In Padasuka village, Lampung, as mentioned in the previous case studies, the organic market customers preferred not to have the BCR when purchasing SHS. The users found that the BCR was a problem for various reasons: 1) some users called the red light as the time when the battery is 'bankrupt' and were unhappy to wait 1 - 3 days for the battery to be recharged 2) they felt the waiting time was restricting their freedom to get access to their own system. Three users, who have owned their system for 14 years, eventually stop using BCR approximately 4–5 years ago. Other users have since followed their way. According to these people, their batteries lasted for approximately four years. Asked about the battery management, and how they knew the time when the energy reserve in the battery was low, one user replied "that was the time when TV could not be switched on but it's important to have the lights on". It is found that freedom of choice is an important issue in this case as it relates to the energy service availability/continuity.

In the village of Pusu, NTT Province, where SHS were delivered in a contractual model, facilitated by the Womitra Foundation, a village electricity management called "Pengelola Listrik Desa" (PLD) was formed. PLD will be discussed further in Section 4.4. The PLD office contains spare parts such as distilled water, lamps, inverters and fuses which were made available to the users (see Figure 4). PLD Pusu management, visited in May 2005, stated that the payment rate was above 95%. By comparison, previous PVEC governmental projects achieved less than a 20% repayment rate⁸, something attributed to the top down approach and absence of adequate after sales service (Fitriana, 2003). The provision of after sales infrastructure is imperative in maintaining continuity of PVEC energy service to keep customers satisfied. Therefore availability is the key in this case.

4.3. Acceptability: Case Study 3 – Socioeconomic and Local Capacity Issues

As stated previously, it is imperative that PVEC is more than a technocratic solution. If PVEC delivery is beyond the absorptive capacity⁹ of a local culture, then inappropriate promotion of PVEC can result in waste and failure rather than an increase in local productivity. For instance, in the village of Nusa, NTT, there was a PV Water Pumping System that no longer pumped water to the distribution tanks despite the fact that the system was still operating as the water from the creek no longer filled the main pool/pond. A micro-hydro expert from IBEKA, a Jakarta-based NGO, speculated that this lack of water could have been the result of aquifer shift/movement which can happen with limestone geological structures. Other possible causes for the interruption of the water supply could be block pipes, management issues or human intervention. With no institution to approach or rectify the problem, the local people have reverted to their old routine of walking some distance to collect water from the creek, but now it is in the shadow of modern technological means that would supposedly save their time and energy.

⁸ Personal communication with BPPT, Jakarta, October 2003.

⁹ Absorptive capacity is defined as the access and utilization of external knowledge (Knudsen et al, 2001).



Figure 5. (Left): PVEC for a Water Pumping System in Nusa Village, NTT. (Middle) Standing by the empty pond, these local people have just finished bathing and doing their laundry at the creek. (Far/Right): Local ladies carrying water, and wood, collected from the creek.

With an appropriate approach however, PVEC has proved to increase local productivity and quality of life. In Padasuka village, for example, many children are no longer at risk while preparing kerosene lamps, while also having a better quality of light in which to study at night. Two fathers admitted that before having SHS there was always a 'blue' tired feeling when leaving the farm at dusk, only to find the house in darkness and then, if they had a portable diesel generator, of firing it up, and having disputes within the family if the children had not prepared the kerosene lamps.



Figure 6. (Left) The E7 PV-Wind-Diesel Hybrid system. (Middle 1) People in Oeledo Village, NTT, watching a TV program in a house that subscribes to the E7 isolated grid AC PV-Wind-Diesel hybrid system. (Middle 2) "Ublik" kerosene wick lamp (inset), as it is called in Lampung, also called "Pelita" or "Tio Oek" in NTT. Kerosene lamps are the domain of children at this age; Padasuka Village, Lampung. (Right) A Weaver of traditional NTT fabrics in Pusu Village.

The E7 PV-Wind-Diesel Hybrid system installed in Oeledo Village, NTT, did improve household income from off-farm business activities such as telecommunication kiosks, shops and sewing machines (Dauselt, 2004). With colour TV and parabolic antennas, local people can now get access to information and entertainment. The wealthier people were found to be happy in sharing the TV service with their neighbours, and proud to play such a social role in the community. Having had their lives improved from the AC hybrid system, the PLD management expressed concern related to the future of their village when the system reaches its end of life. Oeledo is so isolated, 2 hours driving and 4 hours by ferry from Kupang that the national electricity grid may not reach them within the foreseeable future. The hybrid system granted to the village had generated significant revenue from its 127 subscribers; however it is still insufficient to finance re-investment for a similar system.

In Pusu village, the user empowerment program accompanying the introduction of SHS, introduced by Womintra, proved to increase local productivity. Local ladies, many of whom are skilful weavers, admitted there was a significant improvement in home income as they are able to work until long after the sun sets. The "down side" of this however, is that as women are able to work extended hours, with availability of SHS light, further burdens are unconsciously imposed on them, exacerbating cultural hierarchy rather than genuinely improving the women's quality of life.

4.4. Implementation: Case Study 4 – Role in Project Activities

Actively involving local communities in the project design can offer strength for local institutional culture. As introduced in the Sub-Section 4.2, in NTT, the PLD was created to manage PVEC at village level. The PLD was initially formed during the E7 “Renewable Energy Supply System (RESS)” rural electrification project that was completed in 2000 in Maluku, South Sulawesi and NTT (E7, 2001)¹⁰. PLD members comprise of SHS users, and the officials (head, secretary/treasurer, and technician) were also elected from among the End Users. The formation of the PLD was facilitated by Womitra whereby the Field Officer lived in the target village for a couple of months. There are now 16 PLDs operating in NTT. The rule of the scheme, meeting schedules etc, were defined and agreed in the PLD meeting attended by all members and officials. Payments are collected at the PLD office rather than being picked up from each member’s house. In the case of PLD Pusu, payment is collected on the 20th and 21st each month between the hours of 9–12 am. The general meetings of the PLD are conducted quarterly on the 20th of the month.

As stated, accommodation of stakeholders’ interests is of prime importance to maintain PVEC sustainability. As mentioned previously, the payment rate at PLD Pusu is above 95%. This payment rate reflects not only user’s satisfaction with the energy service they obtained, but also the transparency, accountability and their significance as community members because they have their say about their role and have a perception of living in a democratic environment.



Figure 7. (Left and Middle) Pusu Village, NTT, visited on May 20th 2005: A SHS user is paying the SHS monthly instalment at the PLD Office; a traditional structure constructed by End Users. The PLD officials were elected from within the End Users. The organisational structure, map of the village indicating SHS locations, the list of End Users and the quarterly meeting schedule, are all displayed on the PLD office wall. (Right) Products of traditional weaving made by local women are exhibited during the payment session.

Case Study 5 – Economic and Political Environment

Implementational Environment looks at the socio-economic, political and legal environment in which PVEC is operating. A facilitating climate is required for PVEC to operate sustainably. As an example, at the peak of the economic crisis, Indonesian GDP per capita dropped sharply from USD 1,100 in 1996 to USD 480 in 1998 whilst the Indonesian Rupiah lost 80% of its value against the USD during the same period, changing from less than Rp 2,400 to Rp 16,000 per USD. When the economic crisis peak was over, the Rupiah settled at between 8,000-9,000 per USD; less than one third its pre-crisis value. At this time, a 50 Wp PVEC lighting package, originally targeted for rural dwellers with annual incomes of less than Rp 4 million (BPS, 2002), was valued at approximately 4 million rupiahs (PSG, 2003), which is obviously well outside of their reach. An AusAID project, launched in 1997 under the Government of Indonesia’s “One Million Roof Project”¹¹ scheme (Djamin, 1997), managed to complete the installation of 36,600 SHS in nine eastern provinces during 1997-1999 (Fitriana, 2003) as it had planned. The E7 also completed the installations of 175 SHSs and 50 kW PV-Wind-Diesel Hybrid in Eastern Indonesia in 2000 (E7, 2001). However the AusAID project’s ability to generate further

¹⁰ Personal communication with former E7 RESS Residential Project Manager, Kupang, May 2005.

¹¹ Operated by BPPT, a Jakarta-based governmental research agency concerned with the assessment and application of technology.

installations from a revolving fund¹² was limited after the financial crisis as people's purchasing power weakened. The World Bank/GEF Semi-commercialisation project, also launched in 1997 under the Government of Indonesia's "One Million Roof Project" scheme, concluded with just 8,054 sales out of an initial target of 200,000 units (Leitmann, 2004). The unfavourable economic conditions clearly blocked both PVEC dealers and potential users (Leitmann, 2004) from accessing PVEC.

The recovery of the Indonesian economy and political framework appears to have instigated another wave of enthusiasm for PVEC within Indonesia. The World Bank, one of PVECs sponsors, discerned the potential of the "son/daughter of SHS in a more favourable economic climate" (Leitmann, 2004). However, a supportive investment climate needs to be created, for instance by providing incentives in the fiscal regime (eg by tax and import duty exemption) (Leitmann, 2004; Pratomo, 2004). Indonesian Decentralization, enacted by constitution in 1999 and implemented by 2001, resulted in more institutional power being transferred to local authorities (Turner, 2003). Local governments have now designed their own rural electrification programs rather than relying on those planned and delivered by central government. The Bengkulu government, in Sumatra Island, has delivered a PVEC lighting system to its people, in collaboration with central government both in terms of finance and expertise¹³. In NTT Province, Eastern Indonesia, the local government collaborated with NGOs to install 1,000 SHS units in 11 isolated villages replicating the E7 model (Astawa Rai, 2004). The strengthening of local capacity (for the government departments, the implementing agency, installation personnel, and end users) remains central to maintaining PVEC sustainability.

5. FINAL REMARK

The PVEC Sustainability model proposed in this study offers a holistic approach to accommodate the interests of all stakeholders encompassing Sponsors, Facilitators, and End-users. As stated previously, accommodating the interests of key stakeholders is imperative for PVEC to be sustainable in off-grid applications. This model also covers PVEC attributes and PVEC technology transfer; which unfortunately are not possible to be fully explored in this short paper, that are all essential for PVEC diffusion in the local socioeconomic culture. These three elements – stakeholders, attributes and transfer – are all essential elements in the technology transfer paradigm which dictates the acceptance of new technology that can potentially contribute to improving the sustainability of the lives of rural communities. The limitation of this model is that it requires a substantial effort to implement in practice.

6. ACKNOWLEDGMENTS

We wish to thank AusAID, the School of Electrical Engineering of UNSW, STTNAS College, BPPT Indonesia and BP Solar Australia for their exceptional support and cooperation. AusAID provides a scholarship for the author's postgraduate study, and together with the School of Electrical Engineering of UNSW, STTNAS College, and BP Solar provided financial support for our fieldwork in Indonesia. Both BP Solar and BPPT allowed us to have open discussions with their highly experienced staff and provided valuable materials concerning PVEC projects experiences. Our gratitude also goes to the official members of governmental institutions, PVEC consultants, universities, PVEC industries, NGOs and PVEC end users who we visited during our fieldwork in Indonesia. It is our hope that the good cooperation will continue and the results of our study will be of value to all parties.

¹² An anecdotal report mentioned that both the BANPRES Presidential Aid (1990-1991) and AusAID (1997-1999) projects generated revolving funds, making it possible to install a further 2,100 SHS units in Kolaka, North Molucca and Natuna islands (Personal communication with BPPT, Jakarta, February 2003).

¹³ Personal communication with BPPT, Jakarta, October 2004.

7. REFERENCES

- Astawa Rai, A., (2004), *Development Growth in Eastern Indonesia*, Paper presented at the BPPT – NEDO International Workshop on Solar Energy Utilization, Jakarta, October 2004, ISSN 1829-9210 (CD ROM).
- BPS, (2002), *Statistical Year Book of Indonesia – 2001*, Central of Statistical Bureau, Jakarta, p573, ISSN 0126-2912.
- Cabraal, A., Cosgrove-Davies, M., Schaeffer, L., (1996), *Best Practices for Photovoltaic Household Electrification Programs - Lessons from Experiences in Selected Countries*, the World Bank.
- Dauselt, C., (2004), *PV-Wind-Diesel Hybrid System: Decentralized Electricity Supply in Nusa Tenggara Timur Province – An AIJ Project of the E7 Initiative*, Paper presented at the BPPT – NEDO International Workshop on Solar Energy utilization, Jakarta, October 2004, ISSN 1829-9210 (CD ROM).
- Djamin, M., (1997), *The One Million Homes Photovoltaic Rural Electrification Program – Progress Report*, Energy Technology Laboratory, The Agency for Assessment and Application of Technology, BPPT, Jakarta.
- E7, (2001), *E7-1 Project: Indonesia – Renewable Energy Supply Systems, Final Report*, Lessons Learned, http://www.e7.org/PDFs/E7_RESS_Indonesia.pdf
- Fitriana, I., (2003), *Evaluation of Socio-Economic Aspects of Solar Home System Programme Implementation in Indonesia*, MSc Thesis, University of Flensburg, Germany.
- IEA, (2004), *Photovoltaic Power Installed in Selected Other Countries*, <http://www.oja-services.nl/iea-pvps/isr/index.htm>
- IEA, (2003), *Institutional Framework and Financial Instruments for PV Deployment in Developing Countries*, IEA PVPS Task 9, September, www.iea-pvps.org
- IEA, (1999), *Indonesia – IEA PVPS Task III Stand-alone PV Systems*, International Energy Agency, <http://141.51.158.34/iea/DevelopingCountries/Indonesia.pdf>
- Knudsen, MP., Dalum, B., Villumsen, G., (2001), *Two Faces of Absorptive Capacity Creation: Access and Utilization of Knowledge*, Denmark, (2001), web.cbs.dk/departments/ivs/link/seminars/praest_absorptivecapacity.doc
- Krause, M., Nordstrom, S., (2004), *Solar PV in Africa – Experiences with Financing and Delivery Models*, http://www.undp.org/gef/undpgef_publications/publications/solarphotovoltaics_africa.pdf
- Leitmann, J., (2004), *Solar Energy Dissemination Experiences*, World Bank, Paper presented at the BPPT – NEDO International Workshop on Solar Energy utilization, Jakarta, October 2004, ISSN 1829-9210 (CD ROM).
- Outhred, H., Healy, S., Retnanestri, M., Tukunga, T., (2004), *Experience With Off-Grid Photovoltaic Systems in Tonga and Indonesia*, Paper Presented at The 14th International Photovoltaic Science & Engineering Conference (PVSEC), Bangkok, January 2004.
- PLN, (2004), *PLN Statistics 2003*, Perusahaan Listrik Negara/The Indonesian National Electricity Utility, Jakarta.
- PLN, (2003), *PLN Statistics 2002*, Perusahaan Listrik Negara/The Indonesian National Electricity Utility, Jakarta.
- Pratomo, Y., (2004), *Renewable Energy Policy in Indonesia*, Paper presented at the BPPT – NEDO International Workshop on Solar Energy utilization, Jakarta, October 2004, ISSN 1829-9210 (CD ROM).
- PSG, (2003), *Solar Home Systems – Final Report 2003*, WB/GEF Project Support Group, Jakarta.
- Retnanestri, M., Healy, S., Outhred, H., (2005), *Off-grid Photovoltaic Sustainability and Its Potential Role in Facilitating Sustainable Rural Development*, Paper presented at the World Regional Energy Conference and Exhibition, Jakarta, 17-21 April 2005.
- Retnanestri, M., Outhred, H., Healy, S., (2003), *Off-grid Photovoltaic Applications in Indonesia: An Analysis of Preliminary Fieldwork Experience*, Destination Renewables - Australia and New Zealand Solar Energy Society, Annual Conference, Melbourne, 26-29 November 2003, ISBN 0975065017 (CD ROM).
- Retnanestri, M., Outhred, H., Healy, S., (2003), *Off-grid Photovoltaic Applications in Indonesia: A Framework for Analysis*, Paper presented at the Australasian Universities Power Engineering Conference (AUPEC), Christchurch, New Zealand, 28 September – 1 October 2003, ISBN 0-473-09867-9 (CD ROM).
- Rogers, Everett., (2003), *Diffusion of Innovations*, Free Press, New York, ISBN 0743222091.
- Turner, MM., (2003), *Decentralization in Indonesia*, Asia Pacific Press, ISBN 0731536975.
- WEC, (1999), *Achieving Equitable Access to Sustainable Energy*, World Energy Council, <http://www.worldenergy.org/wec-geis/>