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## **OFF-GRID PHOTOVOLTAIC SUSTAINABILITY AND ITS POTENTIAL ROLE IN FACILITATING SUSTAINABLE RURAL DEVELOPMENT IN INDONESIA**

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In many parts of the developing world where an electricity grid remains out of reach for the foreseeable future, Photovoltaic-based Energy Conversion Systems (PVEC) can help fulfill rural energy needs [1] by providing people with electricity for basic services and amenities [2]. Despite the massive number of PVEC installations and the considerable support and initiatives provided by donors and the government, to date the Indonesian PVEC market remains below its technical potential, which is projected to be 900 MWp [3]. For PVEC to be sustainable in off-grid applications in Indonesia, it is imperative that PVEC is delivered to rural Indonesian communities in an institutional framework that accommodates the interests of all stakeholders. A holistic approach to project design and implementation of off-grid PVEC is also required for PVEC to contribute to sustainable rural development. Further, if the benefits of PVEC to facilitate sustainable rural development is to be maximized, PVEC needs to be an integral part of national strategies for sustainable development, poverty reduction and other development plans and targets [4]. This paper describes a study of the sustainability of off-grid PVEC applications in Indonesia that is currently underway and a postscript describes how this work has recently been extended to Disaster Risk Management (DRM) in the wake of the December 2004 Tsunami Disaster.

Key words: Off-grid PVEC applications, PVEC sustainability, rural development.

### I. INTRODUCTION

The 1980's witnessed a worldwide enthusiasms for PVEC. Hankins [in 5] summarized the 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 of 66,215 Indonesian villages has been electrified, however only 52% [6] of households have actually been electrified leaving approximately 26 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

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number of PVEC projects have operated in Indonesia since the 1980s. The Indonesian situation is not unique and runs parallel to that other developing countries such as the Philippines, Sri Lanka and many in Latin America, which also received donor support under bilateral agreements [5]. To date approximately 28 MWp [7] of PVEC power has been generated across Indonesia from various residential and public applications including lighting, water pumping, communication, health care, etc. Findings from our preliminary fieldwork suggest that in at least some instances, villagers have responded positively to the introduction of off-grid PVEC [8]. However, despite the massive number of PVEC installations and the considerable support and initiatives provided by the government, to date the PVEC market remains below its technical potential, which is projected to be 900 MWp. 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 [9]. 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 [10, 11] preventing wider PVEC acceptance.

## II. 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 issues of the institutional, socioeconomic, technological and environmental dimensions of PVEC delivery. In this study, these dimensions will be explored through the lens of accessibility, availability, acceptability and implementational structure and environment of PVEC delivery, defined in the PVEC Sustainability section below. Earlier papers describe the institutional framework for off-grid PVEC applications in Indonesia [12] and discuss the outcomes of preliminary fieldwork undertaken in late 2002 and early 2003 [8].

The methodology of the project includes literature research, field research in villages where PVEC has been installed, and interviews with key stakeholders (manufacturers, distributors, research agency, and end users). As part of this research project work plan, field research is proposed to obtain first hand knowledge from case studies related to PVEC sustainability in Indonesia. This field research follows up preliminary fieldwork undertaken in early 2003, which included visits to governmental institutions, donor agencies, PVEC industries, NGOs and PVEC sites. In the substantive phase, the author intends to revisit PVEC stakeholders to conduct in-depth interviews. The interviews will be used to identify 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.

### III. PVEC SUSTAINABILITY ISSUES

Findings from our preliminary fieldwork suggest that in at least some instances, villagers have responded positively to the introduction of off-grid PVEC in Indonesia [8]:

- PVEC systems have been used for economic activities, which is a measure of the acceptance of PVEC into rural life;
- PVEC systems have been kept as back up power after grid connection, which is a measure of user satisfaction with PVEC reliability;
- PVEC users are willing to invest in bigger capacity 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, as mentioned previously, the Indonesian PVEC market remains below its technical potential, just 28 MWp installed to date compared to IEA's projection of 900 MWp. As with other developing countries, many technical, institutional, cultural and economic difficulties are experienced when introducing this technology. The review by Nieuwenhout et al [13] of experience with SHS in developing countries noted "more and more doubts have arisen about the effectiveness and suitability of small PVEC systems for rural development. Many organizational, financial and technical problems appear difficult to tackle" [13].

As an example of a positive installation, 102 PVEC lighting systems were installed in the village of Sukatani in West Java in 1988 as a pilot PVEC village program. The project at Sukatani was monitored and periodic site audits of the technical and social aspects were conducted [14]. Studies of Sukatani, including its financial management, were well documented. Fifteen years after the installation of these lighting systems the villagers still express a positive attitude and have kept their PVEC systems, for back up power, after grid electricity arrived in 2001 [8]. 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 [8].

A preliminary observation of a different solar lighting project indicated that many users found that the PVEC lamp was too bright for sleeping and that it could also attract the unwanted attention of thieves to their homes. Consequently, after 10 pm, villagers reverted to traditional kerosene lamps, effectively eliminating the energy savings of PVEC and also increasing their expenditure on energy as they now pay for both fossil fuel and PVEC lighting. One PVEC user who installed motorcycle bulbs to reduce the illumination was surprised to find that energy consumption increased, exhausting the stored PVEC energy very quickly [8].

It is imperative that PVEC is more than a technocratic solution that departs from local culture. If PVEC delivery is beyond the absorptive capacity<sup>2</sup> of a local culture, the innovative promotion of PVEC can result in waste and failure rather than an increase in local productivity. More importantly, PVEC should be delivered to rural Indonesians in an institutional framework that accommodates the interests of all stakeholders. PVEC must become an enabling technology; able to strengthen the rural socioeconomic culture to facilitate rural development and promote care for the environment. 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 [9].

Financial and institutional instruments such as a strategic subsidy, business skill training and distribution infrastructure proved to give PVEC a better chance of success [16]. The World Bank/GEF projects located 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 users<sup>3</sup> and allowing providers to establish a distribution network in rural areas [16]. These cases demonstrate the importance of access to finance making PVEC more accessible, hence affordable to users and profitable to providers.

Actively involving local communities in the project design can offer strength for local socioeconomic culture. The E7 project in NTT province, which introduced SHS and PVEC-Wind-Diesel Hybrid systems, improved household income from off-farm business activities such as telecommunication kiosks, shops and sewing machines [17]. This project was facilitated by a local NGO and maintained by PLD, a village electricity enterprise, the members of which were selected from within the communities [18].

As a comparison, previous PVEC projects achieved less than a 20% repayment rate [19], something attributed to the top down approach and absence of adequate after sales service [11]. The provision of after sales infrastructure is imperative to maintain continuity of PVEC energy service to “keep customers happy” [20]. Therefore availability is the key in this case.

If the benefits of PVEC to facilitate sustainable rural development are to be maximized, PVEC needs to be “an integral part of national strategies for sustainable development, poverty reduction and other development plans and targets” [4]. This can be achieved, for instance, by integrating PVEC in the strategies for improving the Human Development Index (HDI), see Section V below, and Millennium Development Goals (MDG) through the provision of PVEC energy service for education, health, clean water, sanitation and productive activity purposes.

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<sup>2</sup> Absorptive capacity is defined as the access and utilization of external knowledge [15].

<sup>3</sup> However customers are limited to wealthier rural households [16].

#### IV. PROPOSED PVEC SUSTAINABILITY EXAMINATION MODEL

A PVEC Sustainability model, denoted as the “Four Pillars of PVEC Sustainability” in this study has been developed and is shown in Figure 1 below. This model has been developed to capture how the institutional, socioeconomic, technological and environmental issues of PVEC delivery are addressed by maintaining *accessibility, availability, acceptability*<sup>4</sup> and the viability of the *implementational structure and environment* of PVEC delivery. **Accessibility** refers to the provision of reliable modern energy services at a sustainable level of price [21], addressing financial and institutional issues of PVEC delivery. **Availability** covers both quality and continuity of energy supply [21], addressing institutional and technological issues of PVEC delivery. **Acceptability** covers both societal and ecological goals [21] addressing cultural, socioeconomic, institutional and technological capacity issues of PVEC delivery. **Implementational** structure and environment look at to what extent the institutional, socioeconomic, political, legal and administrative framework provide conducive environment for PVEC to operate sustainably, addressing institutional issues of PVEC delivery. Many components are listed under each heading, see Figure 1, for examination purposes. Some of them will be elaborated in the following sections.

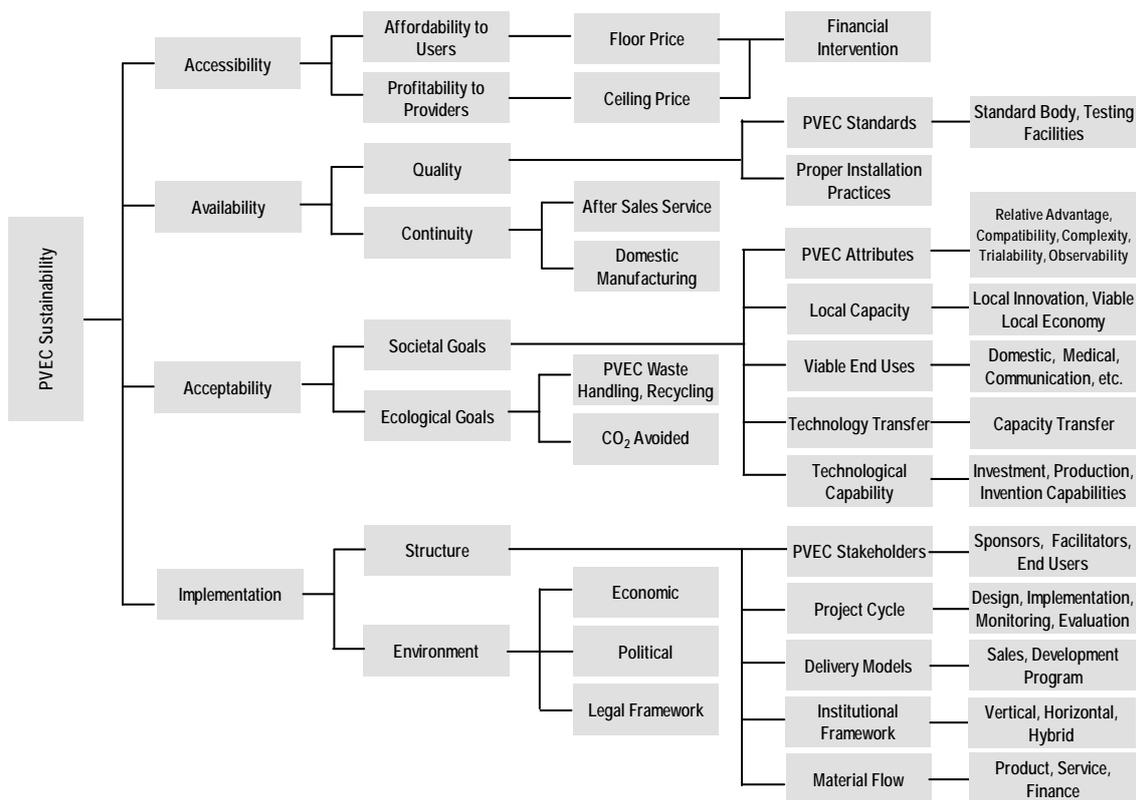


Figure 1. The proposed PVEC Sustainability examination model.

<sup>4</sup> The terms Accessibility, Availability and Acceptability are the interlinked “three energy goals” as proposed by the WEC [21]. 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.

#### 4.1. Accessibility

Accessibility contains Affordability and Profitability components. These will be used to understand the gap between Floor Price and Ceiling Price, and the Financial Intervention required (access for both providers and users to loan, credit, subsidy, grants, etc) to assist PVEC market uptake until the market can sustain economic operation. From the institutional perspective, accessibility can also mean, for instance, how local government can get access to outsourced PVEC projects. In this study, perspectives from PVEC providers, end users, donors and governments will be required for assessing the Accessibility requirements. Input from stakeholders will be used to understand how financial and institutional barriers of PVEC delivery can be addressed.

#### 4.2. Availability

Availability 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 domestic PVEC Standards and Certification, and proper installation practices is a requirement to maintain product quality, competitiveness and customer guarantees. Together with Domestic Manufacturing, Domestic PVEC Standards and testing facilities are essential to maintain self-sufficiency. Views from PVEC providers and testing bodies are required which will be used to address technical and institutional barriers.

#### 4.3. Acceptability

The Societal Goals, listed under Acceptability, cover PVEC Attributes, Local Capacity, Viable End Uses, Technology Transfer and Technological Capability. Under PVEC Attributes there are Relative Advantage, Compatibility, Complexity, Trialability and Observability components. These components are five characteristics of innovation diffusion, adopted from Rogers [22], which dictate users acceptance. Relative Advantage is used to understand whether PVEC is perceived as “better than the idea it supercedes” which is often expressed in terms of economic profitability, social prestige (status seeking), and other benefits [22]. Compatibility is used to understand whether PVEC is perceived as “being consistent with the existing values and needs” [22] 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” [22]. 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. This can potentially be facilitated through technology transfer capacity building.

Acceptability also covers Ecological Goals that are used to understand the handling of PVEC waste as well as the benefits from avoidance of fossil fuel use (for instance CO<sub>2</sub> environmental benefits or the cost of transportation for purchasing fuel).

Input from all PVEC stakeholders is required for the Acceptability component, which will be used to address cultural, socioeconomic, institutional and technological capacity issues of PVEC delivery.

#### 4.4. Implementation

Implementational Structure includes PVEC Stakeholders, Project Life Cycle, Delivery Models, Institutional Framework and Material Flow. PVEC Stakeholders include Sponsors (donors, governments, PVEC manufacturers), Facilitators (research agencies, local government, PVEC distributors, banks, NGOs, village cooperatives) and End-users (individual, public)<sup>5</sup>. 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 [22]. In this study, the institutional framework of existing PVEC models will be studied; whether vertical, horizontal or hybrid, and their respective performance will be compared. Material Flow illustrates how PVEC is channeled from the point of production to end uses, and is used to understand the benefits perceived by all PVEC Stakeholders in relation to the flow of financial and PVEC energy services.

With regard to Delivery Models, PVECs are commonly delivered to rural communities through Sales or Development models [23]. The PVEC market potential in developing countries, mainly SHS, has been summarized in a hierarchical fashion comprising of Cash, Credit, Subsidized and No Market segments [24]. The Cash market size has been reported to be only about 5% and various forms of financing should allow a further 50% to enter the market [25]. In this study, the Cash to No Market order is scaled over the Sales-Development continuum, see Figure 2.

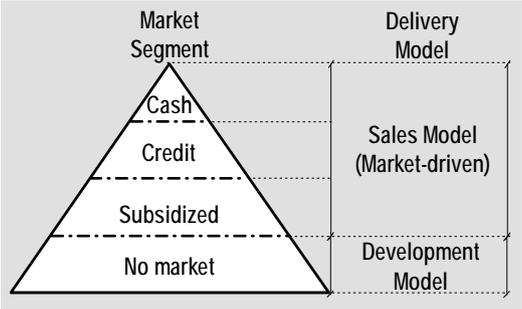


Figure 2. PVEC Delivery Continuum.

The three top segments (Cash, Credit, Subsidized) are designated for the Sales Model analysis, while the No Market segment is designated for the Development Model analysis (see Figure 2). The extent to which the Sales and Development models can demonstrate PVEC’s sustainability will be investigated through case studies that explore the extent to which the rural communities are able to move towards the Sales end of the delivery continuum. The

<sup>5</sup> The stakeholder classification of Sponsors, Facilitators and End-users is equivalent to the terms Change Agency, Change Agent and Clients used in Rogers [22].

more rural communities are able to move towards the Sales end of the delivery continuum, observed through an increasing PVEC market demand, the more sustainable PVEC should be as PVEC strengthens the rural socioeconomic culture while at the same time also strengthening the country's PVEC industries, entrepreneurship and institutions.

Implementational Environment looks at the socio-economic, political and legal environment in which PVEC is operating. A conducive 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, plummeting 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 [26], was valued at approximately 4 million rupiahs [27], which is obviously well outside of their reach. An AusAID project, launched in 1997 under the Government of Indonesia's "One Million Roof Project"<sup>6</sup> scheme [28], managed to complete the installation of 36,600 SHS in nine eastern provinces during 1997-1999 as it had planned [11]. The E7 also completed the installations of 175 SHSs and 50 kW PV-Wind-Diesel Hybrids in Maluku and South Sulawesi in 2000 [18]. However the AusAID schemes ability to generate further installations from a revolving fund was limited after the financial crisis as people's purchasing power weakened<sup>7</sup>. 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 [16]. The unfavorable economic condition clearly blocked both PVEC dealers and potential users [16] from accessing PVEC.

The recovery of the Indonesian economy and political framework appeared 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 favorable economic climate" [16]. However, a conducive investment climate needs to be created, for instance by providing incentives in the fiscal regime (eg by tax and import duty exemption) [16, 30]. Indonesian Decentralization, enacted by constitution in 1999 and implemented by 2001, resulted in more power being transferred to local authorities [31]. Local governments have now designed their own rural electrification programs rather than 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 expertise [32]. In NTT Province, Eastern Indonesia, the local government collaborated with NGOs to assemble 1,000 SHS units in 11 isolated villages replicating the E7 model [33]. The strengthening of local capacity (for the government departments, the implementing agency, installation personnel, and end users) remains central to maintaining PVEC sustainability.

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<sup>6</sup> Operated by BPPT, a Jakarta-based governmental research agency concerned with the assessment and application of technology.

<sup>7</sup> 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 [29].

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 that are all essential for PVEC diffusion in the local socioeconomic culture. These three elements – stakeholders, attributes and transfer – are essential elements in the technology transfer paradigm which dictates the acceptance of new technology. See Rogers [22] for a detail discussion on technology transfer and the diffusion of innovations. The limitation of this model is that it requires a substantial scale of research.

For the purpose of understanding the extent to which a PVEC project has addressed PVEC sustainability requirements, the author intends to interview a broad spectrum of PVEC stakeholders involved in PVEC project operation and observe the project's success from a number of indicators including PVEC longevity, repayment rate, the increase of market demand and expansion of service area coverage.

## V. PVEC AS A TOOL FOR SUSTAINABLE RURAL DEVELOPMENT

The basic goal of rural electrification scheme in Indonesia is to promote social and economic development in rural areas. Within this scheme, PVEC was offered as an innovative answer to rural energy needs by providing people with electricity for basic services and amenities. The question that arises is: To what extent must PVEC be incorporated into the local socioeconomic culture, to help promote sustainable rural development (SRD), before it becomes widely accepted?

The Human Development Index (HDI) and Human Poverty Index (HPI)<sup>8</sup> will be used as themes and benchmarks in this study, for the purpose of analyzing PVEC and SRD, owing to their global acceptance. However other relevant local measures can also be used when applicable. As examples, the three-tiered *swasembada* (self-sufficient), *swakarya* (transitional) and *swadaya*<sup>9</sup> (traditional) village classifications devised by the Ministry of Home Affairs, the two-tiered IDT<sup>10</sup> (least developed/poor village) and the non-IDT devised by Bappenas, BPS and the Department of Home Affairs, and finally the *Sejahtera* (well off) and *Pre-Sejahtera* classification devised by the Department of Health<sup>11</sup>.

As of 2002, approximately 110 million Indonesians do not have access to grid supply [8]. These rural inhabitants are generally farmers, artisans, craftsmen, fishermen or small-scale traders. It has been argued that “lack of adequate energy services in rural areas has social as well as environmental and health effects” [35]. This claim is confirmed by observation of the correlation between the electrification ratio, Human Development Index (HDI) and Human

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<sup>8</sup> HDI is a measure of life expectancy, educational attainment and standard of living while HPI is a measure of poor health, illiteracy, access to clean water and earning below a dollar a day [34].

<sup>9</sup> Village classification based on seven indicators: source of income, level of production, level of modernization, existence of village institutions, education level, community spirit, and availability of infrastructure.

<sup>10</sup> This classification measures the village remoteness/isolated-ness level and the percentage of the population without access to clean water and health facilities and is used as a benchmark to provide special development funds to poor villages. As of 2003 71 out of 440 Indonesian regencies had reported they still have poor villages in their region.

<sup>11</sup> This classification measures the family's ability to fulfil basic needs.

Poverty Index (HPI) at provincial levels in Indonesia. This is illustrated in Figure 3. The Indonesian HDI has been improving since 1975 when it measured a mere 0.467 reaching 0.623 in 1990 and eventually 0.692 in 2002 [34]. The poverty index has reduced from 25.2% in 1998 to 17.2% in 2002. However, this figure still leaves Indonesia ranked 111<sup>th</sup> in the world below its Asian counterparts such as Malaysia, Thailand and Philippines. Within Indonesia the HDI and HPI varies between provinces and districts. Interestingly these two indicator trends varied along with that of the electrification ratios: HDI is higher and HPI is lower with a high electrification ratio, see Figure 3. Jakarta, seen in the graph, having the highest rate of electrification ratio shows the highest HDI and lowest HPI; which is far above the national average. The two provinces having the lowest rate of electrification ratio, NTT and Papua, indicate the lowest HDI and highest HPI as they are positioned to the extreme left of the graph. These trends demonstrate the degree of correlation between the availability of electricity and socio-economic development in Indonesia. The graphs also indicate that education, access to communication, health and other socio-economic related issues need to be at the forefront of rural and national development planning in Indonesia for the people to achieve progress.

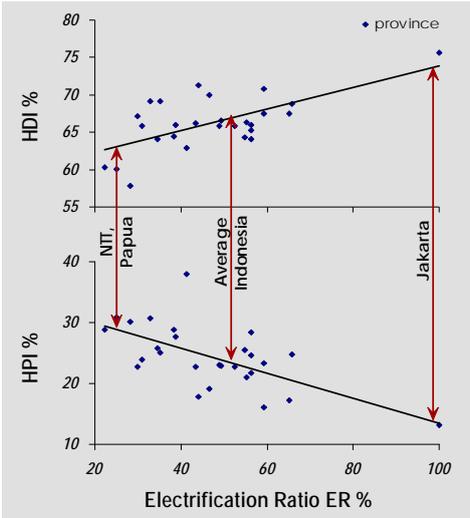


Figure 3. Trends and Correlation of the Indonesian provincial Electrification Ratio, HDI and HPI.

Rural electricity needs in developing countries are relatively small, averaging 900 kWh per capita compared to 9000 kWh in industrialized countries [21]. In Indonesia, the figure was 410 kWh per capita in 2002 [6]. Extension of the electricity grid to areas with such low demand is not economically feasible [21] as lower voltage transmission results in high network losses and the low load factor entails a high operating cost. Decentralized power, including diesel, biomass, hydro, wind and solar, is a more viable option which also offers an opportunity for local control [21]. Provided that sustainability issues are well addressed, PVEC can help fulfill rural energy needs and function as a tool for SRD, especially for the isolated and lagging regions with least primary energy options and where dependency on fossil fuel supply creates service reliability issues.

The study of Campen et al [1] presents an inventory of PVEC end uses in rural energy sectors ranging from domestic use, social services, to agricultural and off farm/commercial sector productive activities. They include SHS, PVEC for medical storage, school and training centres, internet server for telemedicine and E-commerce, water pumping, water purification, irrigation, village cinema and battery charging stations [1]. However, one issue that remains for PVEC sustainability; is how accessibility, availability, acceptability and implementation are maintained for its delivery. As mentioned previously, PVEC should be more than a technocratic solution because “energy provision is not technology provision, it is about understanding the role that energy plays in people’s lives, and helping to lift the constraints that are imposed when it is not available” [36]. When PVEC can meet the energy needs of rural societies, “in the most effective manner possible”, they should “obviously be used” [2].

In reference to the PVEC Delivery Continuum model, see Figure 2, commercial sectors (both on-farm and off-farm) and wealthier households, representing the top three segments of PVEC market, can be served by using the Sales model of PVEC delivery. For this purpose, market needs should be encouraged and the capacity of the market actors needs to be strengthened. The objective of PVEC Sustainability for the “Market Driven” segment is how PVEC can contribute to the strengthening of rural socioeconomic culture by creating jobs, strengthening private sector entrepreneurship and achieving self-funding status. The main actors in this segment will be PVEC businesses and commercial End-users.

The No Market segment, see Figure 2, can be treated by using the Development model of PVEC delivery. Considering the complexity of the socio-economic issues inherent in this segment, socially complex and economically marginalized, a cross sectoral and programmatic approach is required to accommodate the energy need of this particular segment. In fact it has been suggested that rural electrification must be treated within the context of rural development at large as electricity, as an isolated measure, does not in itself lead to rural development [37]. Electricity should be treated as an input to rural development and is intended to invest in social capital rather than focussing on a short-term goals with a finite impact. PVEC, as part of SRD strategy, can potentially improve HDI and HPI through the provision of health, education, clean water and poverty eradication. For this to happen a cross sectoral and programmatic approach among respective governmental departments will be required. Of similar importance is the active involvement of the local community as the beneficiary of the program. A sponsor-driven PVEC project can potentially create dependency upon external support and experts, leading to lack of local ownership. PVEC should be designed as a community-driven project, focussing on local capacity enhancement, for the welfare of the targetted societies. The main actors of this segment will be the local community, NGOs and local government. The main objective of PVEC Sustainability for the “No Market” segment should be how local communities are enabled and can eventually move from a survival state towards the Sales end of the PVEC Delivery Continuum, see Figure 2.

To summarize, PVEC-based rural electrification for the Market Driven and the No Market segments of rural societies need different approaches and different actors that can also be unique for particular setting or situation. Nevertheless, the main issues remain tied to the PVEC Sustainability requirements, that is how socioeconomic, institutional, technological and environmental dimensions of PVEC delivery are addressed by maintaining PVEC

accessibility, availability, acceptability and implementation. Provided that PVEC sustainability issues are well addressed PVEC can potentially contribute to promoting social and economic development and facilitate SRD.

## VI. POSTSCRIPT

With the Tsunami disaster that struck Aceh on 26 December 2004 the problems addressed by the analytical framework developed in this study appear particularly well suited to addressing disaster vulnerability. Coupled with the country's high population, lack of disaster awareness and mitigation strategies Indonesia's geographical characteristics recurrently expose the Indonesian community to disaster<sup>12</sup> threatening the progress of socio-economic development. A reduction strategy is therefore essential to address the Indonesian communities' vulnerability. The study has thus been refocused to explore the role that PVEC played as part of the disaster response as well as the role that it may play in Disaster Risk Management (DRM) to reduce the vulnerability of village communities to future disasters.

Being stand-alone and utility independent, PVEC can supply autonomous power for communication, lighting, medical storage, and water purification needs during disaster relief operations. As an example, in the aftermath of the hurricane Andrew that struck South Florida in 1992, portable PVECs were quickly mobilized to provide power for lighting, vaccine storage and radios in several field medical clinics for relief operation [39]. Their modularity also bodes well for domestic, tele-education, information dissemination and early warning systems for disaster mitigation and preparedness purposes. An example is where PVEC is used to monitor the flow of the river to warn of upstream flooding in Colorado and power emergency sirens to warn against tornados in Denver [40]. In Aceh, Bappenas<sup>13</sup> recommended that the use of surface water for drinking should be minimized for 2 to 5 years to come for fear of contamination as a result of the December 2004 Tsunami. Portable PVEC reverse osmosis systems can potentially fulfill this task and provide the community with clean water during the recovery period. In response to the Aceh Tsunami, the January 2005 Jakarta Tsunami Summit declared its commitment to establish a tsunami early warning center in the Indian Ocean region. Being self-contained, PVEC can provide energy services for the disaster early warning scheme, for instance for public information dissemination (radio receiver, transmission repeater), communication (satellite telephone), emergency sirens, and disaster awareness promotion through education and access to information (internet).

Provided that adequate DRM institutional infrastructure is in place, PVEC can potentially be embedded into the DRM scheme through DRM institutional capacity building, knowledge transfer and partnerships between DRM and PVEC stakeholders. It is necessary to identify potential institutional and socioeconomic capacities at local level, the strategies set in place for DRM, which PVEC applications best fit each phase and which outsource resources and expertise are required to facilitate PVEC-assisted DRM implementation. Partnership with and facilitation by national or international organizations, who have resources and relevant expertise, encompassing various sectors and multi-disciplines are necessary for this purpose.

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<sup>12</sup> In the period 2001-2002 alone the region was shaken with earthquakes of magnitude between 5 and 7.6 more than 200 times [38].

<sup>13</sup> The Indonesian National Development Planning Agency.

## VII. FUTURE PLAN

As part of the overall research project plan fieldwork will be conducted in 2005. This would be the substantive fieldwork foreshadowed as a follow up to the preliminary fieldwork undertaken in December 2002-February 2003, which included visits to governmental institutions, donor agencies, PVEC industries, NGOs and PVEC sites. While the preliminary fieldwork identified key issues used to construct the analytical framework for this project, the substantive fieldwork will be used to collect substantive data for analysis. In the substantive phase, the author intends to revisit PVEC stakeholders to conduct in-depth interviews.

## VIII. ACKNOWLEDGEMENT

We wish to thank AusAID for providing scholarship for the author's postgraduate study, and BPPT Indonesia and BP Solar Australia for their exceptional cooperation. BP Solar provided financial support for our preliminary fieldwork and 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 and PVEC industries who we visited during our preliminary 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.

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