The I3A Framework – Enhancing Off-grid Photovoltaic Energy Service Delivery in Indonesia

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ABSTRACT

This paper describes an interdisciplinary research project to investigate the sustainability of off-grid Photovoltaic Energy Service (PVES) delivery in Indonesia. The project was introduced at the WRERCE conference in 2005 where results from the preliminary fieldwork undertaken in late 2002 and early 2003 were presented. Following the preliminary fieldwork, more substantive fieldwork was carried out in 2005. The general objective of this research project is to understand how PVES can contribute to improving the sustainability of rural Indonesian communities without access to the electricity grid. It adopts an interdisciplinary approach that combines social and engineering perspectives to address sustainability issues. The I3A (Implementation, Accessibility, Availability, Acceptability) Sustainable PVES Delivery framework [1,2] was developed in this project to assess sustainability and was used to assess three off-grid PVES case studies from Lampung, West Java and Nusa Tenggara Timur (NTT) provinces. The overall objectives of the I3A framework are to acknowledge the interests of all stakeholders, maximize equity, assure PVES continuity and institutionalize PVES by utilizing and enhancing pre-existing community resources to leave host communities with the capacity to meet evolving needs. A key conclusion is that, to be sustainable and equitable, off-grid PVES projects should be implemented in an institutional framework that provides sound project management and addresses PVES accessibility (financial, institutional and technological), availability (technical quality and continuity) and acceptability (social and ecological). Drawing on those insights, ways to enhance off-grid PVES delivery in rural situations in Indonesia are recommended.

Keywords: Off-grid PVES Applications, PVES Delivery Sustainability, the I3A Framework.

1. Off-grid PVES Sustainability Prospects & Issues within the Indonesian Context

Since the 1980s, approximately 10MWp of off-grid photovoltaic (PV) power has been installed in Indonesia for powering lighting, water pumping, communication, health clinics, etc [1,3]. However, PV Energy Service (PVES) delivery has yet to prove its sustainability and remains inaccessible to many remote Indonesian communities [1,2,4]. The following key findings related to PVES sustainability were drawn from the preliminary and substantive fieldwork:

- **Institutional:** Successful PVES installation has involved the establishment of local electricity institutions, which are indicators of the strengthening of local institutional capacity. However, in some cases, the lack of follow-up assessment of field performance and local capacity to adapt PVES to local conditions has led to inadequate after-sales service and eventually PVES failure. In such cases, a more decentralized and cross-sectoral programmatic approach is required that pays greater attention to meeting user needs and maximising user outcomes.
- **Financial:** Some revolving funds have been generated from past government projects and PVES has been used to support income-generating activities, which are indicators of financial sustainability. However, off-grid PVES delivery is characterised by scattered markets that are expensive to service and PV modules remain expensive. Thus, first-cost barriers to wide commercial PVES deployment remain. On the other hand, the energy service model can exhibit lack of transparency and poor funds management. Potential solutions involve strategic financing, smarter subsidies and the development of viable rural economies.
- **Technological:** Domestic manufacturers of balance of system components and panel assemblers continue to strive to penetrate both the domestic market and export markets of other developing countries. However, inadequate warranties, after-sales service infrastructure and spare parts availability coupled with poor installation practices continues to undermine PVES continuity. Potential solutions include sound local institutions, local capable agents, more robust PVES hardware, stronger warranties and a wider range of PVES products.
- **Social:** Given the right conditions, PVES has improved rural community well-being by providing access to clean water, good quality lighting, access to telecommunications and infotainment and through supporting job creation, which together can improve the Human Development Index (HDI), reduce the Human Poverty Index (HPI) and improve

energysecurity. However malfunctioning PVES hardware introduces externally imposed problems which in some cases can lead to social fragmentation. It is imperative that off-grid PVES delivery avoids a narrow technocratic approach and pays greater attention to social inclusion, the satisfaction of rural energy requirements and to supporting income generation.

- **Ecological:** PVES can be ecologically friendly and noise-free, enhance sustainable rural development and contribute to GHG mitigation strategies, as well as reduce the need to transport fossil fuels, in itself a GHG emitting activity. However, inappropriate waste disposal can undermine such worthwhile objectives. PVES project design and delivery should adopt life-cycle impact assessment principles including sound waste handling strategies.

2. Project Description & Methodologies

The research project discussed in this paper combined social and engineering research methods and qualitative fieldwork to develop a systematic approach to achieving good PVES delivery outcomes. The broad aim of the research project was to: 1) Investigate the sustainability of energy service delivery in off-grid rural situations in Indonesia and the extent to which sustainable energy services can enhance rural social capital (RSC), viewed as part of community resources (CR) as a whole, and encourage social innovation (SI) to facilitate sustainable rural development (SRD) for remote communities. 2) Recommend ways to enhance the sustainability of energy service delivery in off-grid rural situations in Indonesia. The methodologies of the research include literature research, qualitative field research in villages where PVES has been installed and interviews with a wide range of PVES stakeholders in Indonesia (involving 150 respondents from governmental institutions, donor agencies, PVES industries, NGOs, and PVES sites).

Figure 1. 1) The WB/GEF SHS customer at Cirata Lake, West Java (Feb-03), 2) The organic market SHS store in Lampung (May-05), and 3). A SHS payment session at PLD Pusu (May-05).

The I3A Sustainable PVES Delivery framework, discussed in Section 3 below, was used to assess the following three PVES case studies, which are also illustrated in Figure 1:

- Case study 1, a self-reliant organic SHS market in Lampung province: This organic market (OM) emerged from a formal SHS market that collapsed due to the 1997 Asian financial crisis. The thousand stranded customers still required after-sales service and became business opportunities for the former sales representatives and technicians of a failed PVES company.
- Case study 2, the 1997-2003 World Bank/GEF SHS semi-commercial project in Lampung, West Java and South Sulawesi provinces: This project provided 20% consumer subsidy, enacted SHS standards and facilitated the certification of Indonesian PVES testing facilities. The initial sales target was 200,000 SHS units but the project was severely affected by the 1997 Asian financial crisis, resulting in only 8,054 sales by project end [5,6,7,8].
- Case study 3, the PLD (*Pengelola Listrik Desa* or village electricity management) concept in Oeledo and Pusu villages, NTT province: The PLD concept (formed from among the users) was initiated in this 1997-2000 E7 AIJ (Activities Implemented Jointly) project as a CDM test-wise tool. A PV-Wind-Diesel hybrid system was installed in Oeledo village, Rote Island. The PLD concept was later replicated in other parts of NTT, including Pusu village, in which 150 SHS units were installed during 2003-2005 [9,10,11].

3. The I3A Framework: A Model to Enhance PVES Delivery Sustainability

The I3A framework, see Figure 2, is a holistic approach based on the integration of three main theories: Sustainable Development (SD), Social Capital (SC), and Diffusion of Innovation (DOI), with the WEC's three energy goals (3A) [13]. The I3A framework refers to Implementation that maintains PVES Accessibility, Availability and Acceptability [13] to address the institutional, financial, technological, social and ecological sustainability dimensions of PVES. It views PVES as an enabling technology that can enhance rural social capital (RSC) and encourage social innovation (SI) to facilitate sustainable rural develiopment (SRD). Table 1 summarizes the theories and concepts employed in the framework.

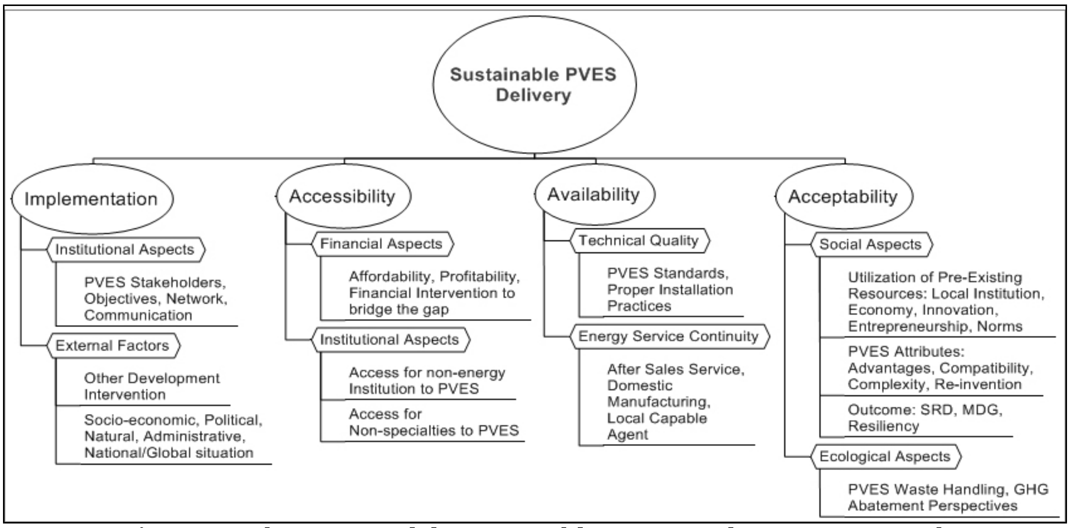

Figure 2. The I3A Model: Sustainable PVES Delivery Framework

Table 1. Theories and Concepts Employed in the I3A Analytical Framework

Theories & Concepts	Main Ideas
Sustainable Development (SD)	**Definition**: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [14, p8]. **Elements:** Institutional, Financial, Technological, Social, Ecological. **Role**: A high level concept used as an underlying principle
The WEC's 3A Energy Goals	**Definition**: "Accessibility to modern, affordable energy for all; Availability in terms of continuity of supply and quality of service; and Acceptability in terms of social and environmental goals" [13]. The 3A's are used as benchmarks for on-going innovation of PVES technology (social innovation) following project completion . **Elements:** Accessibility, Availability, Acceptability. **Role:** To achieve sustainability and address equity issues
Diffusion of Innovations (DOI)	**Definition**: "The process in which an innovation is communicated through certain channels over time among the members of a social system" [14, p5]. **Elements:** Innovation, Channel, Social System. **Role:** to explain PVES system attributes, delivery process & mechanism, stakeholders & their roles. The term KPDAC Continuum (mnemonic for Knowledge-Persuasion-Decision-Adoption-Confirmation) is introduced to explain stakeholders position in the innovation-decision process [14].
Social Capital (SC)	**Proposed definition for SC**: Dynamic resources in both structural & cognitive terms that, subject to the ways in which they are used, may increase, decrease or remain constant overtime. **Elements:** Network, Trust, Norms, Reciprocity. **Role:** to explain PVES delivery resources, outcomes, ensuring greater social inclusion in the PVES delivery process. SC is seen both as a resource for and an outcome of PVES delivery

4. Discussion: The I3A Framework and PVES Case Study Assessment

4.1. **Implementation** looks at the PVES social system: the stakeholders and their objectives, skills, interrelationships and roles in PVES delivery. For good PVES project outcomes, it is necessary to create a civic network that acknowledges the interests of all stakeholders, encourages their active participation and promotes self-reliance. The enabling environment describes external factors that may affect PVES delivery. Figure 3 shows the general principles and Table 2 describes the PVES social systems for the three case studies.

The facilitator plays a central role as the channel between the change agency (sponsor) and clients (users) and is required as long as there are socioeconomic and/or technical gaps between the sponsor and users. A facilitator seeks to secure the adoption of the innovation by the clients in a direction deemed desirable by a change agency, balancing this with selecting the right innovation to meet clients' needs. To ensure that the interests (individual and common) of all stakeholders in the PVES social system are acknowledged, it is necessary to understand at project commencement at what stage the clients are in the innovation-decision process, dubbed the KPDAC continuum in this research. The appropriate role that a facilitator should play at each stage is summarized in Table 3, in which the I3A Framework's Availability & Acceptability domains are also indicated. They will be discussed in Sections 4.3 and 4.4 respectively.

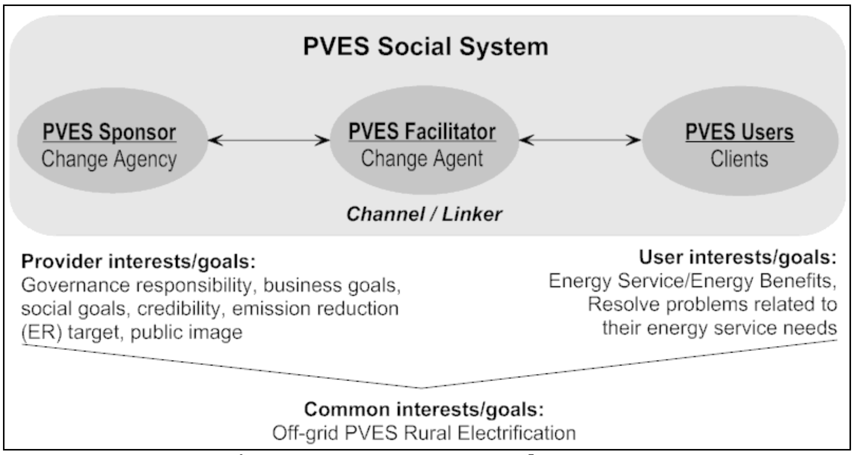

Figure 3. A PVES Social System

Table 2. Summary of the PVES social system for each of the three case studies

	Case Study 1 – Organic Market	Case Study 2 – WB/GEF	Case Study 3 – PLD Concept
Project Objectives	Looking after "stranded" SHS customers	SHS dissemination using market mechanism	CDM test-wise tool
Stakeholders			
Sponsor	OM Entrepreneurs	WB/GEF, GOI	E7, GOI, NTT Government
Facilitator	OM Entrepreneurs	Participating SHS Dealers	Womintra NGO
Users	SHS Users (in Central Lampung)	SHS Users (Cirata & Lampung)	Hybrid & SHS Users (Oeledo & Pusu)
Local agent	OM Entrepreneurs	Rural Outlets	PLD
PVES hardware	SHS (new & second hand)	SHS	PV-Wind-Diesel Hybrid System & SHS
Delivery model	Market-based	Market-based	Developmental
Interrelationship	Informal, horizontal (decentralized)	Formal, vertical (centralized)	Formal, hybrid (vertical & horizontal)

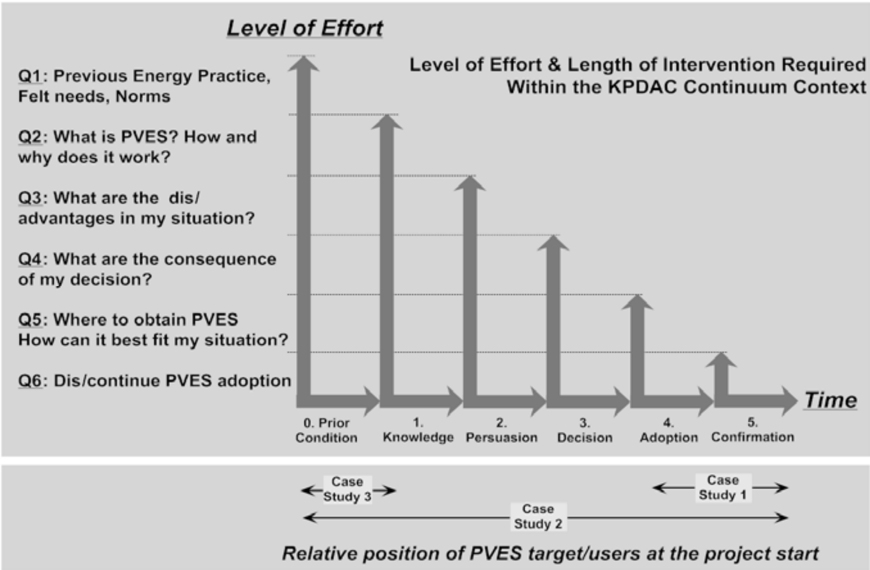

Figure 4. The magnitude of effort and length of intervention required for sucessful PVES delivery in each case study as a function of user position in the KPDAC continuum

The position of stakeholders at project start in each case study is indicated in Figure 4, which also indicates the level of effort required to achieve successful PVES delivery. Users in case study 1 had reached stages 4 and 5 (many users had used SHS for 14 years; users negotiated directly with providers related to payment terms; reinvention had occured with users deciding to bypass BCR[1]). Users in case study 2 spanned the whole KPDAC continuum (from ones who were unfamiliar with SHS to ones who purchased an additional SHS in addition to a pre-existing SHS purchased from an organic market), while users in case study 3 were in stage 0 (skeptical that sunlight and wind could be converted to electricity). As indicated in Figure 4, the earlier the users are in the KPDAC continuum (eg case study 3), the more effort is required as there are more questions to be answered to complete the KPDAC process. During the implementation period, an enabling environment is also required. For instance the 1997 Asian financial crisis severely affected the WB/GEF project, although in case study 1, with the availability of local capable agents, the crisis became a business opportunity instead of the SHS market collapsing.

Table 3. The innovation-decision process [14, pp 168-170], projected into PVES perspectives, and the role of facilitator [14, pp 368-370, with some modifications[2]].

The Innovation – Decision Process (KPDAC)			The Role of Facilitator	Availability	Acceptability
0	Prior Conditions	Previous energy service practice; Felt needs and problems related to energy service	Diagnose problems, assess client's needs, shed light on alternative ways to address existing problems	**T1, Implementation Period**	**T1, Conditional Acceptance**
1	Knowledge	When one is exposed to the existence of PVES and has an understanding of how it works	Establish information-exchange relationship: Knowledge awareness, promotion, education, provide sufficient and accessible information		
2	Persuasion	When one forms un/favorable attitude towards PVES, which is a function of the perceived PVES attributes[3]			
3	Decision	When one decides to adopt or reject PVES			
4	Adoption	When one puts PVES into use; Re-invention[4] might occur	Installation, user education, provide technical assistance		
5	Confirmation	When one seeks reinforcement of PVES already in use, but may reverse this decision if one experiences difficulties	Stabilize adoption, maintain service continuity to prevent discontinuance; Achieve a terminal relationship; ensure that users become self-reliant	**T2, Beyond Project Period**	**T2, Confirmed Acceptance**

Within the social capital (SC) context, a civic network is required in which all stakeholders actively participate to address their interests. To be able to participate, stakeholders need to have: 1) the capacity (degree of autonomy) discussed in sub-section 4-2, and 2) a social structure that allows them to actively participate on agreed terms. A horizontal, decentralized social structure is more likely to allow equal participation rather than a centralized, vertical relationship. From Table 2, the stakeholders in case study 1 were horizontally interrelated, with users and providers negotiating directly from equal bargaining positions (users and providers understand and agree on what they are buying and selling). In case study 2, users and providers were formally and vertically interrelated and users had no part in project decision-making (users were treated as commercial buyers, provided with a 20% SHS consumer subsidy, protected by standardizing hardware provided by authorised SHS dealers who established rural outlets during the project implementation period). In case study 3, top-down and bottom up approaches were combined[5]. The project facilitator, a local NGO, stationed a field officer in each village for 18 months to facilitate the formation and training of a local management body selected from users.

A local institution based on horizontal connections allows stakeholders to define agreed norms owing to "closure" within the structure [15]. Closure within a small community, characterized by

[1] While SHS (Solar Home System) is well accepted, the BCR (Battery Charge Regulator) is selectively rejected by users.
[2] For instance the original term for stage 4 was "Implementation" rather than "Adoption". The term was changed to avoid overlap with the term "Implementation" used in the I3A framework.
[3] Advantage, compatibility, complexity, functionality, fungibility, etc.
[4] This refers to the degree to which an innovation is changed or modified by users [14, p17] to fit their situation. This phenomenon if often regarded unfavorably by R&D agencies, called "noise" or "distortion" to the innovation, with agencies "feeling that they know best as to the form of innovation that users should adopt" [14, pp180-184].
[5] Top down: the selection of PVES hardware; Bottom-up: the project installation and ongoing operation.

expectations, obligations and trustworthiness [15], can facilitate the continued functioning of the PVES social system as stakeholders can continue to exchange benefits [15] within their bioregion. For instance, in case study 1, users can expect continued PVES service from the fact that local providers (the OM entrepreneurs) can continue to earn income from the after-sales service they provide. Similarly, in case study 3, continued PVES service can be expected from the PLD once it has been established. The rules related to payment and after-sales service mechanisms, which are defined in the PLD meeting, help maintain ongoing functioning of the PLD. In case study 2, the lack of closure between users and the rural outlets (established by the SHS dealers) could pose a threat to the continued PVES service if many rural outlets in the project area closed down[6].

4.2. **Accessibility** deals with addressing PVES equity issues[7] from the financial, institutional and tecnological perspectives. Referring to Figure 2, this component focuses on issues related to affordability, profitability and equitable access to PVES. Table 4 summarizes the delivery models, financial schemes, user position in the KPDAC continuum and user degree of autonomy (Figure 6) for the three case studies.

Table 4. Summary of the delivery models & financial schemes for the three case studies

	Case Study 1 – Organic Market	Case Study 2 – WB/GEF	Case Study 3 – PLD Concept
KPDAC Continuum	Stage 4 – 5 (AC)	Stage 1 – 5 (KPDAC)	Stage 0 (Prior Condition)
Market Segment	Cash/Credit/Subsidized	Cash/Credit/Subsidized	Fully-funded Externally
Delivery model	Market-based (More commercial)	Market-based (More commercial)	Developmental (Less commercial)
Financial Scheme	No external financing, Users' own investment based on flexible scheme	20% Consumer subsidy from GEF, Credit facility from WB	Grant for the capital investment from E7, Users pay for the O&M
Degree of Autonomy, Fig 6	Quadrant I, Most autonomous	Quadrant I & IV, Semi to most autonomous	Quadrant III, Least autonomous

The PVES market in developing countries (mainly SHS) has been described as a pyramid consisting of Cash, Credit, Subsidized and Externally Fully-funded segments [Posorski 2003 in 1], which parallels the more-commercial to less-commercial continuum, see Figure 5. The less-commercial segment exhibits a large gap between affordability (ceiling price for buyers) and profitability (floor price for sellers). Financial intervention is required in this segment to assist market uptake until the PVES market can beome self-sustaining (t_1 condition in Figure 5). The positions of the case studies within the market pyramid and delivery continuum are indicated in Figure 5. The more commercial case studies 1 and 2 used cash, credit and subsidy mechanisms while the less commercial case study 3 was fully funded externally (by the donor or government, with users paying the service fee). Projecting the case studies into the level of effort and length required to achieve sustainable local operation (t_0 to t_1), the less commercial segment required more effort and longer intervention. For instance in case study 3, the facilitator needed to place field officers in the target villages to establish local institutions and implement economy empowerment programs, requiring more resources than the more commercial case studies 1 and 2. Thus, the more and less commercial segments of the PVES market require different approaches and actors to achieve financial sustainability: the more commercial segment requires facilitation to achieve self-funding status, while users in the less commercial segment need assistance to move from subsistence to participation in market society (social recognition).

Recalling Section 4.1, stakeholders (particularly users) need the capacity (autonomy) to actively participate in their PVES social system. Autonomy is influenced by financial and technological capacities (ability to purchase PVES and familiarity with it as expressed in the KPDAC continuum). Figure 6 (a) indicates that users who are wealthier and more familiar with PVES (Quadrant I) are more autonomous compared to users residing in other quadrants. In enhancing PVES Accessibility, facilitators need to be aware of each rural community's economic standing

[6] Continuing PVES service was maintained during the project period. However, termination of the project and the associated subsidy led to a decline in sales and forced many rural outlets to close.
[7] PVES is still not accessible by many remote communities, which lack access to PVES financing, skills and networks.

& PVES technological capability to promote user autonomy effectively. The intervention should aim to move users to Quadrant I in Figure 6 (b) using an appropriate approach, Figure 6 (c).

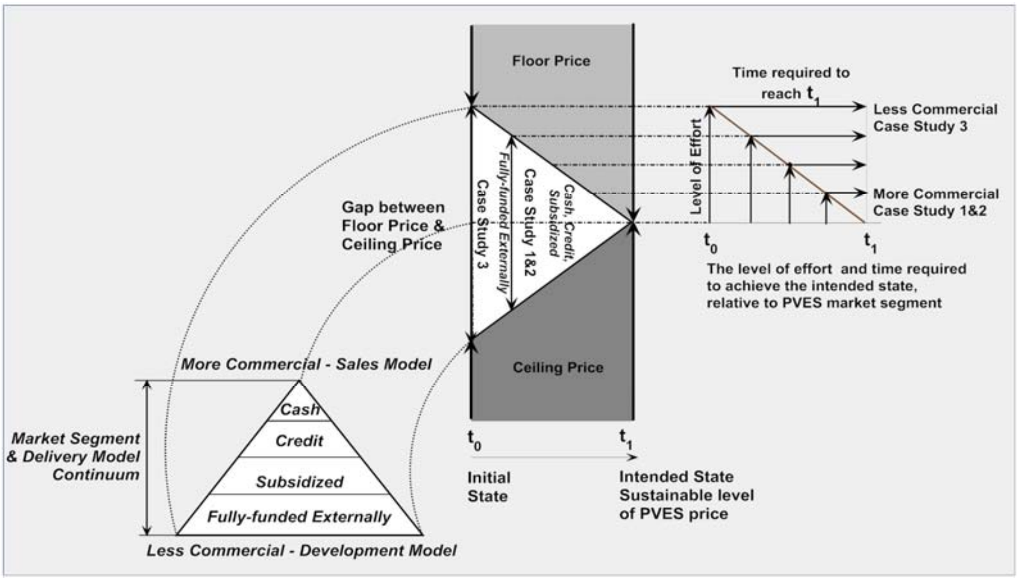

Figure 5. The effort required to achieve financially sustainable market operation

In case study 1, users were autonomous, self-funding and familiar with SHS (users defined the SHS configuration they wanted including not buying the BCR). In case study 2, users were wealthier villagers spanning the whole KPDAC continuum. A commercial approach alone is not sufficient for users residing in early KPDAC stages, who also need more information and communication, recall Table 3. In case study 3, facilitators needed to move users through all stages of the KPDAC continuum and provide capital investment as well as empower the local economy to increase user autonomy.

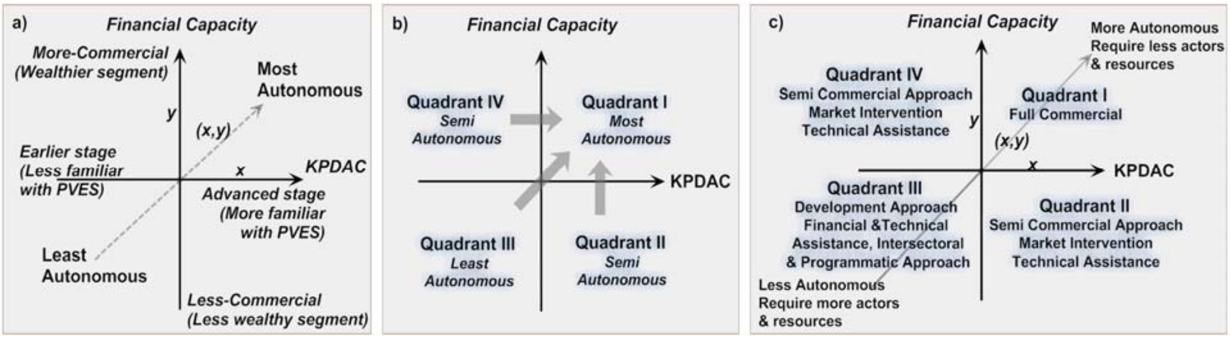

Fig. 6. PVES Autonomy, as a function of Financial and Technological capacities, viewed as a necessary condition for users to actively participate in the PVES social system

4.3. **Availability** focuses on the quality and continuity of energy service supply necessary to maintain user trust and confidence in PVES systems and their providers.

In the KPDAC context, the Availability domain is divided into two time periods called T1 and T2, see Tables 3 and 5 and Figure 7. The T1 period spans the project implementation or deployment period (project life), covering the K-P-D-A (1st to 4th) stages. Key availability issues for the T1 period are technical standards, proper installation practices and hardware warranties. The T2 period refers to the period after the PVES project is completed (beyond project life), covering the C (5th) stage. Key availability issues for the T2 period are after-sales service and PVES operation and maintenance. Facilitators need to be aware of the potential discontinuity between T1 and T2 and its associated risk of PVES discontinuance.

Table 5. Summary of features to maintain PVES availability in the three case studies

T1 & T2 Components	Case Study 1 – Organic Market	Case Study 2 – WB/GEF	Case Study 3 – PLD Concept
T1 – Standards, Proper Installation Practices, Warranties	No formal standards used, refer to past practices; simple I-V testing procedures;	Established National SHS standard complying to IEC; Achieved ISO 25 accreditation for national certification & testing facilities	Referred to IEC, ISO standards, domestic safety laws and standards
T2 - After-sales Service, Spare Parts, Operation & Maintenance	Provided by the OM entrepreneurs as part of their business scheme; 5 year & buy back guarantee for the module	Retail outlets; User Manual provided by SHS dealers; 10 year guarantee for module, 1 year for BCR, 9 months for battery	PLD technicians available at designated hours; spare parts available at PLD office; User's Manual provided by the NGO

Robust PVES hardware is essential to withstand various physical conditions in the field. However, within the context of PVES availability, robust hardware addresses, at best, half of the overall availability requirements. A sound local institution, local capable agents and well-informed users are equally important to maintaining PVES availability throughout its technical lifetime. Malfunctioning PVES will undermine the perceived benefits that PVES may offer, create distrust toward PVES providers and destroy confidence in PVES. Thus, careful attention should be paid to availablity in both the T1 and T2 periods, considering supply and demand side aspects, to maintain T1 – T2 continuity beyond the project life. Case study 1 was a situation where PVES adoption had stabilized, with many users having used SHS for 14 years at the time of my visit in 2005. The OM entrepreneurs had built profitable businesses in after-sales service. They paid occassional visits to users to collect installments and offer spare parts and maintenance services (for instance cleaning batteries). In case study 2, the rural outlets established during the project period provided after-sales service. However, users were concerned that the outlets might close at the end of the credit period. This reflected their lack of confidence in the continuity of PVES energy service delivery once they had fulfilled their credit obligations. In case study 3, the PLDs provided after-sales service and spare parts in designated hours and were available for user consultation during the monthly payment sessions. With a board appointed from among the users, the PLD could maintain user confidence in PVES and its providers.

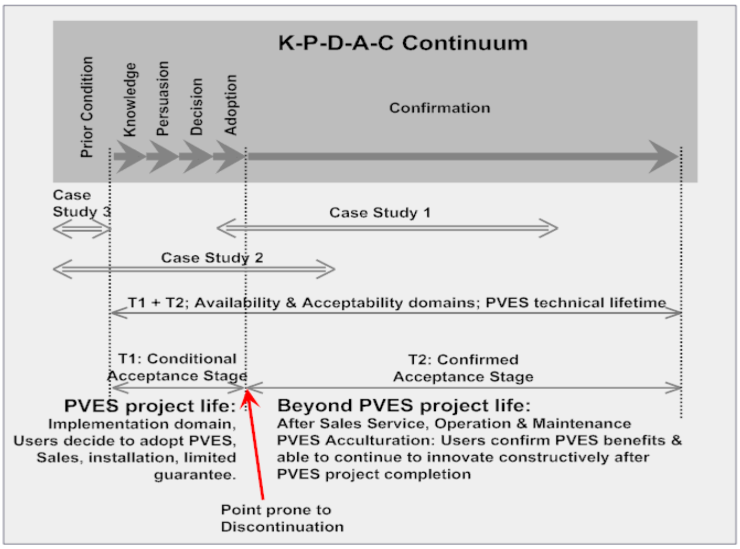

Figure 7. PVES availability and acceptability domains in the KPDAC context, showing **u**ser positions at project start for each case study

4.4. **Acceptability** focuses on the social and ecological perspectives, assessing the extent to which PVES can acculturate into local life, strengthening rural socioeconomic culture and promoting ecological care to facilitate SRD (MDG, social cohesion & community resiliency).

Within the KPDAC context, the Acceptability domain is divided into two periods labeled T1 conditional acceptance and T2 confirmed acceptance, see Table 3 and Figure 7. Acceptability is defined by 1) Sustainable Implementation (Section 4.1), 2) Accessibility (Section 4.2), 3)

Availability (Section 4.3), and 4) the extent to which PVES can satisfy rural energy needs and diffuse into local culture, which is a nexus between PVES attributes and local requirements. Thus users provisionally adopt PVES at T1 and, provided that the acceptability requirements above are all fulfilled, users are able to confirm PVES benefits at T2 and continue to innovate constructively beyond PVES project completion.

PVES benefits mentioned in all case studies included: *financial benefits* (from reduced kerosene and dry-cell battery use and avoiding the need for battery charging. Unlike the grid there is no monthly payment obligation once the SHS is paid off, andevening economic activities such as longer shop operation, handicrafting and tailoring are facilitated), *social benefits* (greater comfort such as better lighting for study, evening social activities, collective TV watching, greater safety such as reduced kerosene fire risk, job creation, entrepreneurship, better health from reducing indoor pollution, reduction in social isolation from access to telecommunications) and *technical benefits* (reliability, practicality, modularity, user-friendly technology compared to portable diesel engines, which require a rope pull start that is impractical for women). Some problems quoted include: *financial barriers* (lack of financial support to bridge the affordability – profitability gap, stakeholders in case study 1 and 2 quoted 50-60% of the current SHS price as being an affordable level) and *social and technological barriers* (BCR is often seen as undesirable and selectively rejected; the banking system is unpopular among rural users; providers expected government and educational institutions to play a greater role in facilitating the adoption of PVES).

Social innovation occured in all three case studies. For example, SHS has been used for swallow bird farming, powering a rural telephone business and as a means of donating to the community. Many users hoped for PVES powered carpentry appliances and radios that could be taken into the field. Given the right approach, PVES can institutionalize into local culture, enhance rather than decrease RSC[8] and facilitate SRD via a PVES civic network and enhanced social cohesion and community resiliency. Referring to Putnam's SC [16], a PVES civic network, characterized by norms, trust and reciprocity, is necessary for good outcomes. Putnam noted that trust, social networks and citizen engagement translate into attractive and safe neighborhoods [16, p37].

Figure 8. PVES introduction into a community should aim to increase RSC: 1) The PV-Wind-Diesel hybrid installation and PLD institution (physical capital and social capital). 2) Neighbors assembled to watch TV in Oeledo (social capital) and 3) Young villagers share the excitement of a new SHS installation in Lampung (social capital).

5. Conclusions & Recommendations

The I3A framework can shed light on the extent to which off-grid PVES can contribute to improving the sustainability of the lives of rural Indonesians by applying the following criteria:

- Sustainable implementation: Promote a civic PVES social system by acknowledging the interests all stakeholders, encouraging their active participation, and enhancing self reliance.

[8] Note that introducing PVES can have both positive (intended) and negative (unintended) consequences. Malfuntioning PVES can create distrust and lack of transparency in fund management can create social fragmentation, both of which would result in a waste of investment.

- PVES accessibility: Build user autonomy so that users have the capacity to participate actively in the PVES social system, with access to PVES financing, skills and networks, thus maximizing PVES equity.
- PVES availability: Understand the potential T1 to T2 discontinuity and ensure availability in both T1 and T2. This requires a paradigm shift from emphasising the hardware dimension of technology to emphasising the software and orgware dimensions.
- PVES acceptability/acculturation: View PVES as an enabling technology (fishing tackle not raw fish). Thus, focus on using the PVES delivery to enhance pre-existing local resources for sustainable rural development rather than on the PVES technology itself.

The main drawback of the I3A model is that it requires substantial effort to implement. However, a similar investment may be necessary to achieve good outcomes regardless of the approach used.

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