# Overcoming Barriers to Renewable Energy Technology Acculturation in Indonesia; Off-grid PV and Hybrid Case Studies

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## Abstract

*This paper discusses the use of a qualitative assessment tool called the KPDAC (knowledge, persuasion, decision, adoption, confirmation) continuum to understand the process and outcomes of renewable energy (RE) technology acculturation in off-grid villages in Indonesia. The KPDAC continuum can also be used as a tool to design strategy for RE technology deployment looking at requirements for RE acculturation and how it can be facilitated. The acculturation of renewable energy (RE) technology is used here to describe the process and outcomes of RE deployment in a community, including the extent to which RE technology acculturates or diffuses into, and becomes part of, the community's ongoing activities. This paper presents assessments of three off-grid photovoltaic (PV) deployment case studies from Lampung, West Java and Nusa Tenggara Timur (NTT, Eastern Indonesia) provinces, using the KPDAC continuum. The assessments indicated that the communities were at different starting points in the KPDAC continuum for RE technology and required different approaches for RE technology acculturation to be successful. Facilitators need to understand how acculturation challenges vary with KPDAC continuum starting point and adopt an appropriate approach if RE technology acculturation is to be successful. Lessons from these project assessments have been used to design a long-term approach to building capacity for RE deployment through educational institutions, undertaken as part of a recently completed Australian Development Research Award (ADRA) research project that was undertaken as a collaborative Australian-Indonesian project. The purpose of capacity building is to create capable agents, who are able to facilitate the RE acculturation process in Indonesia.*

**Keywords:** *Renewable energy acculturation, KPDAC continuum, RE capacity building*

## 1. Introduction

Indonesia is endowed with large renewable energy resources with more than 150 GW of technical potential [1]. Many parties have deployed RE technology (RET) in Indonesia since the 1970s with varying degrees of success. By 2009, 6.4 GW of RE electricity generating capacity had been installed across Indonesia (on-grid and off-grid) and contributed a 4% of RE share of Indonesia's total energy consumption, as opposed to 96% of fossil fuel (coal 34%, natural gas 19% and oil 43%) [1]. Of the 6.4 GW installed, 4.2 GW was large hydro, 1.2 GW was geothermal, 0.5 GW was biomass and the remaining 0.5 GW comprised small scale micro hydro, photovoltaic (PV) systems and wind power [1], installed mainly in off-grid areas with government or donor support.

In 2009, the Indonesian electrification ratio was 64%, leaving more than 80 million Indonesians excluded from the grid [2, p20]. The plan is to increase the electrification ratio to 91% by 2019 [3], however even then it is expected that there will still be 24 million people[1] without access to electricity supply. For off-grid situations, RET has been seen as a solution. Thus, despite the potential and four decades of effort, off-grid RE has not become institutionalised or acculturated in the life of off-grid community. In 2006, the Government of Indonesia (GOI) set a RE target of 17% by 2025, which was elevated to 25% in 2010 [1]. To reach this target however, a careful implementation strategy will be required to ensure RET sustainability (institutional, financial, technical, social and environmental). One necessary measure is to ensure that RET demonstrates its benefits and gets accepted or acculturated in the community's life. This paper attempts to demonstrate the importance of understanding requirements and process for RET acculturation and the capacity building required for that purpose.

[1] Assuming that the present population of Indonesia is 237 million and that the population growth rate for the next decade continues at 1.5% per year as the average was in the decade 2000-2009 [4, p 86], we can predict that Indonesia's population will be 270 million in 2019.

## 2. Methodology

Retnanestri [5] developed the concept of the KPDAC continuum based on the work of Rogers [6] on diffusion of innovations and used it as a means to understand the RET acculturation process and its requirements [6]. According to Rogers, an adopter of an innovation (RET in this context) may undergo an innovation-decision process from "gaining initial *knowledge*[2] of an innovation, to *forming an attitude*[3] toward the innovation, to making a *decision* to adopt or reject, (if deciding to adopt) to *implementation*[4] of the new idea, and to *confirmation* of this decision" [6, p168]. Rogers noted that uncertainty is inherent in the process [6, p168] and that community dynamics may affect the outcome.

Facilitators must guide members of the adopting community through a sequence of steps if they are to adopt RET and confirm its benefits rather than discontinue its use. In the RET context, Table 1 summarizes the five sequential stages of the KPDAC continuum, associated questions for community members to consider, and the respective roles of facilitators. Facilitators play crucial roles in assisting the target community to answer these questions, including diagnosing problems with previous energy practices and suggesting improvements, providing information on alternatives (including RET), assisting in implementation and suggesting ways in which users can continue to harness RET benefits, thus stabilizing its adoption. Establishing and maintaining community consensus is key.

**Table 1.** The RET KPDAC continuum based on Roger's innovation-decision process [6, pp168-170], and the role of facilitator [6, pp368-370]

| | Stages | Definition, Question | The Role of RET Facilitator |
|---|---|---|---|
| 0 | Prior Condition | Previous energy service practice. Felt needs and problems related to energy service. **Q0: Are there alternatives?** | Diagnose problems, assess client's needs, shed light on alternative ways to address existing problems |
| 1 | Knowledge | When one is exposed to the existence of RE technology and has an understanding of how it works **Q1: What is RET? How & why does it work?** | Establish information exchange relationship:<br>- Knowledge awareness,<br>- Promotion,<br>- Education,<br>- Promote consensus,<br>- Provide sufficient and accessible information |
| 2 | Persuasion | When one forms a favourable or unfavourable attitude towards RET, a function of its perceived attributes. **Q2: What are dis/advantages in my situation?** | |
| 3 | Decision | When one decides to adopt or reject RET **Q3: What are the consequences of my decision?** | |
| 4 | Adoption | When one puts RET into use; Reinvention may occur. **Q4: Where can I obtain RET? How can it best fit my situation?** | Facilitate installation, provide user education and technical assistance, consensus building |
| 5 | Confirmation | When one seeks reinforcement of RET already in use, but may reverse this decision if experiencing difficulties. **Q5: Continue or discontinue RE adoption?** | Stabilize adoption, maintain continuity of service to prevent discontinuance; Achieve a terminal relationship; Ensure users become self-reliant |

At Persuasion (attitude forming) stage, the extent to which one forms a favourable or unfavourable attitude towards RE technology depends on its perceived attributes, which might include: 1) Relative advantage - whether RE system might be better than existing practice; 2) Compatibility - whether RE system is perceived as being consistent with the existing values and needs of the users/adopters; 3) Complexity - the degree to which RET is perceived difficult to understand and use. At adoption stage, reinvention may occur, in which adopters change or modify an innovation [6, p17) to fit their situation[5]. While indicating a "selective rejection" [6], reinvention also indicates that adopters have taken charge of the innovation, or in other words the innovation has been institutionalized or acculturated into the user's ongoing practice. See [5] for a more detailed discussion of the conceptual background to the KPDAC continuum.

The remainder of this paper uses the KPDAC continuum to discuss three case studies and is based primarily on [5]. It concludes with an overview of a capacity building activity by STTNAS College based on findings of the Australian Development Research Award (ADRA) research project, which is discussed in [7].

[2] Italicized by the author
[3] This refers to "persuasion" stage which refers to an attitude forming stage
[4] The term "implementation" is referred to an act of "adoption" of the innovation and therefore "adoption" is used instead
[5] R&D agencies may dislike reinvention, calling it "noise" or "distortion" and believing that "they know best as to the form of innovation that users should adopt" [6, pp180-184].

## 3. Case Studies - Description and Discussion

**Case Study 1: Stage 0 (Prior Condition) in the KPDAC continuum**

**1997-2000 E7 PV-Wind-Diesel, in Oeledo village, NTT province:** This project, an AIJ (Activities Implemented Jointly) project, was deployed by the E7[6]in collaboration with the Government of Indonesia (GOI) and NTT government, and was facilitated by Womintra, a Kupang-based NGO. The project installed a PV-Wind-Diesel hybrid system (22 kWp PV, 10 kW wind turbine, 20 kVA diesel generator, Figure 1b) that was subscribed by 127 (out of 354) households in the Oeledo village (an isolated and poor village at project start) by means of an overhead 220V single phase distribution system. The E7 provided capital investment of US$ 1.8 million to fund the equipment and capacity building. The project established a village utility called *Pengelola Listrik Desa* (PLD), the board members of which were elected among the villagers to manage the hybrid system operation.

At first, villagers were skeptical about the idea of generating electricity from sunlight and wind due to their lack of understanding about the existence of RET and how it worked, so they were classified as being at stage 0 or Prior Condition at project start. They were unaware of RET's potential advantages or if it would be compatible with the local cultural and social norms, thus they saw the hybrid system as an alien. To achieve adoption, the facilitators had to work through all of the sequential innovation-decision stages (assess local energy needs, raise the villagers' awareness about the technology, its advantages and what it could do to improve their situation, encourage them to apply it and, once the community agreed to acept it, maintain continuity of the hybrid service to prevent its discontinuance). The stages traversed in the KPDAC continuum and their outcomes were as follows:

- *Prior Condition:* Upon the selection of Oeledo for the potential installation of the hybrid plant, the facilitators started by diagnosing its problems (geographical isolation, poverty, lack of access to energy service), assessing existing community capital (sunlight, wind, fishing and palmyras potential), and motivating community members interest to improve their situation.
- *Knowledge-Persuasion:* 1) The use of SHS to demonstrate how sunlight could indeed be converted to electricity, 2) The promotion and formation of the PLD and 3) Facilitating the formation of local cooperatives to develop and market Oeledo's products to enhance their economic activities (based on the economic potential of fishing and Palmyra handicrafts). The PLD was formed from the villagers and comprised community members who were potential users, who then nominated and elected executive officials such as the head, secretary, treasurer and technicians. Field Officers (FO) were stationed in the village for up to two years to familiarize the community with the project, facilitate PLD establishment, train PLD officials in micro-utility including technical, financial and managerial skills and run an economic empowerment program.
- *Decision-Adoption:* Out of 354 families, 127 families decided to subscribe to the hybrid system. Users paid a down payment (DP) and monthly subscription fee.
- *Confirmation:*A field visit in 2005 indicated that the hybrid system was successfully integrated into Oeledo village life, thus confirming its benefits, as demonstrated by the effectiveness of the PLD, improvement of per-capita income (from economic activities such as ice making for preserving fish), better light supporting longer hours of study, shop operation, handicraft making and evening gathering including shared use of TV, and improved promotion prospects for PLD officials in the local government civil service. The PLD became self-reliant in the operation and maintenance of the hybrid system, initially considered alien to the village culture. Further expansion or replication of the project was hampered by its high capital cost and repair costs for the imported equipment. However local government viewed PLD as a model for isolated grid utility service in NTT if fund becomes available.

In summary, this example required a complete traverse of KPDAC continuum, and both sufficient financial investment and a highly capable agent to guide the community on its journey towards successful acculturation of the hybrid system (assuming that it continues to provide benefits).

[6] Later known as E8 and now Global Sustainable Electricity Partnership, an international partnership of large electricity companies, www.globalelectricity.org/en/

**Case Study 2: Stage 4 (Adoption) to Stage 5 (Confirmation) in the KPDAC continuum:**

**Self-reliant organic SHS market in Padasuka village, Lampung province (1998-present):** The economy of Lampung province is based on agricultural activities including commercial plantations. The organic market (OM) emerged from a formal SHS market that collapsed during the 1997 Asian financial crisis. The thousand stranded customers, who desired after-sales service, became a business opportunity for the former sales representatives and technicians of a failed SHS company. Local entrepreneurs developed this informal SHS market by buying and selling new and second hand SHS of various brands and sizes (typically 50 to 100 Wp). SHS buyers paid the entrepreneurs by DP and instalments based on their seasonal income or other agreed terms without intervention from financing institutions. The stages traversed in the KPDAC continuum and their outcomes were as follows:

- *Prior Condition:* Users were already familiar with SHS use and maintenance as SHS had been used in Lampung since the early 1990s. A West-Java based SHS company had sold thousands of SHS by providing dealer credit. When it collapsed in 1998, the base for the market was already in place due to continuing demand. Thus users had already passed through the stages of questioning SHS functions, its advantages and disadvantages and the consequences of adopting SHS (technically and financially) and were at Adoption stage (4) when the OM entrepreneurs established the market in 1998. After-sales service had been lost with the collapse of the former company and the new entrepreneurs could continue to operate according to market principles to satisfy this demand. Users were already confident buyers who could purchase either a complete package (SHS, lights, battery and controller) or separate components. Reinvention, such as bypassing the battery charge controller (BCR), was common among users because BCR cost about USD20 and was considered troublesome (wasting energy, the red light was associated with energy bankruptcy etc).With careful use the car battery (readily available in the local market) could last up to four years. Another reinvention example was a swallow bird farmer who used a SHS to power a CD player to play recorded swallow songs to attract birds.
- *Confirmation:* A field visit in 2005 indicated that SHS had been fully integrated in Padasuka village life with villagers sharing experiences and components. All parties understood what they were buying and selling and how the market worked, and had the self-confidence to continue the equal business relationship. Villagers had confirmed their decision to use SHS and developed self-confidence and self-reliance, indicating the extent to which SHS satisfied their energy requirements and confirming the value of SHS and their own capabilities. Thus adoption has stabilized although further expansion was hampered by the high cost of new SHS (up to US$500, equivalent to the price of a cow) and low availability of used modules. Users and entrepreneurs suggested that 60% of new module price would be sufficiently affordable for new customers.

In summary, Padasuka villagers had sufficient prior knowledge and self-confidence to manage their own SHS acculturation. With the availability of local skilled workers and potential customers with sufficient income, the collapse of the prior SHS company did not result in SHS discontinuance. The collapsed SHS company can be seen as the initial facilitator that left behind a self-reliant market, with local entrepreneurs becoming subsequent facilitators working with self-reliant users who achieved their own ensuing RE acculturation with peer diffusion through horizontal networks among users.

**Case Study 3: Stage 0 (Prior Condition) to Stage 5 (Confirmation) in the KPDAC continuum**

**1997-2003 World Bank/GEF SHS project in Lampung and West Java provinces:** This semi-commercial project in Lampung, West Java and South Sulawesi provinces, was aimed at accelerating SHS market in off-grid areas where earlier private sales using a dealer-credit model had been demonstrated. The project provided 20% consumer subsidy through a market-based delivery chain. It also sponsored the certification of Indonesian SHS testing facilities. The SHS facilitators were the so-called Participating Distributors (PD), mainly Jakarta-based SHS companies that established retail outlets in project areas, employed local people as canvassers to approach potential users and offered consumer credit through participating Indonesian banks. Total project cost was expected to be USD 118 million (comprising IBRD Loan US$ 20 million, GEF grant US$ 24.3 million and users investment). Each SHS was a standard package of PV module, 3 lights, a battery and charge controller. This project was severely affected by the 1997 Asian financial crisis but sales were later helped by the removal of fuel subsidies, which resulted in price increases for kerosene and diesel fuel in 2000 and 2003. Only 0.5% of IBRD loan and 22% of GEF grant had been used by the end of the project due to weakening financial capacity of Indonesian banks, dealers and users. The stages traversed in the KPDAC continuum and their outcomes were as follows:

- *Prior Condition:* The target communities had sufficient income but did not have access to the electricity grid, such as the agricultural communities in Lampung and the fish farmers in Cirata Lake, West Java. These communities used kerosene and or portable diesel engines to fulfill their lighting and other electricity needs. Within the KPDAC continuum, the users were classified as ranging from Stage 0 (*Prior Condition*) with no knowledge of SHS to Stage 5 (*Confirmation*), those who had previously purchased SHS from the second hand market and were willing to purchase additional SHS.
- *Knowledge-Persuasion:* Facilitators conducted promotional activities (such as radio broadcasting, local newspaper advertisement, exhibition at local events, community meetings, door to door sales or donation of SHS for mosques or community buildings) to familiarize potential customers with SHS and educate them about its benefits.Villagers with civil occupations that had a regular monthly income, such as teachers, civil servants, military officers and labor workers, were more willing to purchase SHS than farmers with uncertain seasonal harvest income who considered the fixed monthly installment problematic. Facilitators then offered farmers payment arrangements that were more suited to their seasonal income. Generally, villagers considered SHS expensive but felt that its benefits (convenience, practicality and saving in fuel expenditure) outweighed its high price.The increase in diesel fuel prices in 2000 and 2003 strengthened this view.
- *Decision-Adoption:* Wealthier villagers were the main adopters. They paid a DP and up to three annual instalments for a SHS. The initial price at project start was USD 100 for a SHS with a 50 Wp module. The price rose to US$ 350-500 with the financial crisis[7] that saw The IDR/USD exchange rate fall to 1/3 of its pre-crisis value. By project end, 8054 sales had been made, less than 5% of the initial target of 200,000 units. 50% of the sales took place in 2003, the final year of the project, five year after the crisis. This was partly due to price increases for kerosene (360%) and diesel fuel (430%). Further adoption was blocked by: 1) the withdrawal of SHS subsidy at project end (resulting in a drop in sales from 60 to 5 units per month as SHS could then only be purchased with cash, which only a small number of wealthier farmers could afford), 2) give away of free SHS by local government which reduced villager’s willingness to buy, 3) lack of regular contact with SHS supplier representatives, 4) disappointment from overselling (many purchasers believed, incorrectly, that SHS could power irons, rice cookers and water pumping), and 5) villagers’ unfamiliarity with a banking system. Reinvention occurred such as: 1) the bypassing of BCR, 2) retrofitting of motorcycle bulbs (to reduce the bright illumination from the fluorescent light and in a misguided effort to save battery energy for TV watching only to find that the stored battery energy was depleted at a faster rate). Overuse of battery occurred, in one case requiring the battery to be replaced four times during crediting period.
- *Confirmation:* A field visit to Lampung in 2005 indicated mixed results with some users confirming SHS benefits such as: 1) increased security, 2) better quality of lighting for study and shop operation, 3) practical and noise free operation compared to diesel engine, 4) fuel saving, 5) shared use of SHS for TV watching, mobile phone charging, evening gathering, 6) donation to mosques. Some other users identified SHS drawbacks such as: 1) fluorescent light too bright for sleeping, resulting in the use of low illumination kerosene lights that doubled their energy expenditure from both buying kerosene and paying SHS installments, 2) the modularity of SHS found to attract thieves, 3) unmet capability expectations leading to discontinuation of SHS.

For future projects, users and dealer representatives suggested that:1) 50-60% of retail price would make SHS affordable to a wider group of villagers, 2) market mapping could identify where commercial markets could work, 3) government and educational institutions could play a more active

[7]The 1997 Asian financial crisis, followed by the political crisis, weakened both the business environment and consumer’s purchasing power, creating a difficult environment for the project to achieve its objectives. Had the 1998 Asian financial crisis not stalled the project progress, the outcome of the project could have been different. The fact that there were 8054 sales following the crisis indicated the market potential in the three project areas.

role in SHS socialization, promotion and education to facilitate SHS acculturation, 4) fish farmers at Cirata Lake in West Java, revisited in early 2009, expressed their hope that a similar SHS market would be reintroduced to serve the local needs again.

Case study 3 indicates the challenges SHS facilitators face when dealing with users spread widely across the KPDAC continuum. A commercial approach may work for villagers in the later stages of the KPDAC continuum (more confident users). However, it is problematic for users in the earlier stages as they are less confident and require more (costly) facilitator intervention to provide information and assistance - problematic for dealers on a narrow profit margin. Project design for this semi-commercial model should take into account the initial position of potential users on the KPDAC continuum and, if appropriate, incorporate a community empowerment approach similar to case study 1 for those in early stages, rather than relying on the market approach alone, as well as collaborating with local entrepreneurs such as those described in case study 2.

## Generalization of the Three Case Studies

Figure 1 indicates the initial position of PV users in the KPDAC continuum for each case study as well as the corresponding level of effort and length of intervention required. In general, the less familiar the users initially are with RET (indicated by an early position in the KPDAC continuum), the greater the effort, resources and length of intervention required for RE acculturation. Facilitators need to understand and address these requirements.

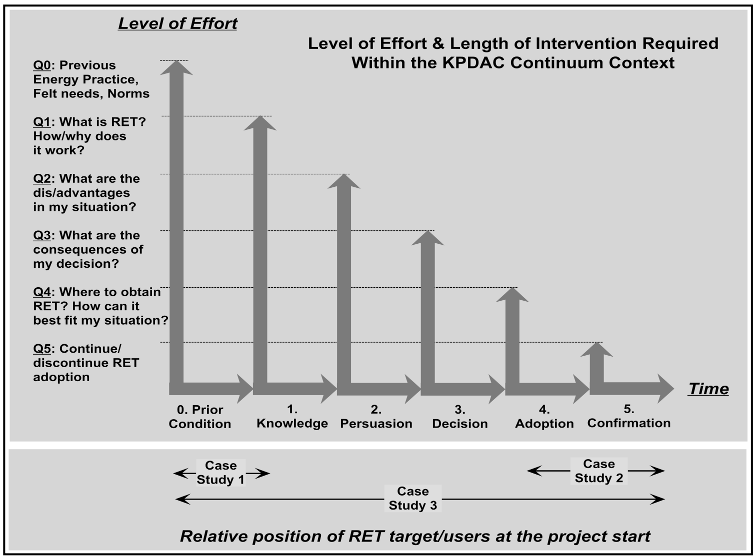


Fig.1a: The KPDAC continuum (illustration is adapted from [6, p170]), level of effort and length of intervention required for RET acculturation, and the position SHS users in the continuum for each case study at project start.
Fig.1b (above): The PV-wind-diesel hybrid system in Oeledo village, May 2005.
Fig.1b (below): The STTNAS study tour at a PV water pumping system in Jogjakarta, June 2010.

## RE Capacity Building Activities to Facilitate RET Acculturation

Despite the potential benefits of RET, Indonesia lacks people with the requisite knowledge and practical experience in its design, manufacture, installation, operation and maintenance. Capable facilitators with sufficient knowledge and skills are needed to diagnose problems with current energy practice and identify alternatives, provide information and education, supervise appropriate RET installations and support their on-going operation and maintenance. Lessons from the above case studies have contributed to the design of an approach to RET capacity building for educational institutions, undertaken as part of the recently completed ADRA research project. The goal of this RET capacity building program is to educate capable agents who can facilitate the acculturation process, thus overcoming barriers to RET acculturation in Indonesia. STTNAS, a private engineering college based in Jogjakarta, is a collaborator in the ADRA research project and participated in developing a model for RET capacity building by an educational institution. In 2009 and 2010, groups of STTNAS students and staff (35 people in each group) undertook study tours to geothermal, photovoltaic, micro hydro, wind, jatropha and biogas sites, factories and research facilities in Jakarta and the Indonesian provinces of West Java, Central Java and Jogjakarta (Figure 1b). Study tour participants were organised in mixed teams of Electrical, Mechanical and Civil Engineering, Chemistry and Geology students and staff to expose and explore the interdisciplinary nature of RET and develop interdisciplinary skills. The students presented their findings in seminars that explored the study tour outcomes, see http://www.ceem.unsw.edu.au/content/RenewableEnergyinIndonesia.cfm?ss=1

Stage 1 of the KPDAC continuum, Knowledge, is where one gains understanding of what RET is and how and why it works. The study tour provided participants with that experience by means of visits to manufacturers and field sites to understand the operation and maintenance of RET. Study tour participants greatly valued this opportunity. Further training and experience would allow tour participants to diagnose problems with current energy practice and identify alternatives, provide information and education, supervise RET installations and troubleshoot to keep RET operating. RET has been acculturated if it remains in operation such that user can continue to harness energy services. Engineering colleges have the potential to play an important role, by providing education and practical experience in RET engineering. Similar capacity building initiatives at other Indonesian universities would facilitate RE acculturation, taking into account the lessons learned from the ADRA research project including the STTNAS capacity building program.

## 4. Conclusions and Recommendations

(1). The KPDAC continuum is useful in assessing and designing a process for RET acculturation. The KPDAC assessment is qualitative and could complement quantitative approaches.
(2). Lessons from the case studies revealed that if target users are early in the KPDAC continuum, they will face greater acculturation challenges and more resources will be required to support them in that transition.
(3). Market mapping or clustering would greatly facilitate RET acculturation by identifying available local resources as well as the position of a target group in the KPDAC continuum, so that an appropriate approach to RET deployment can be designed.
(4). Educational institutions can play a crucial capacity building role to support wider deployment of RET, by educating capable agents (facilitators) able to facilitate the RET acculturation process.
(5). All of the above would assist Indonesia to achieve its future RET deployment target.

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