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Diffusion of photovoltaic systems for rural electrification in Thailand

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Abstract
This paper studies a pilot project in which photovoltaic systems were installed in thirty-six places in the remote areas of Thailand with no access to electricity. One sub-project out of thirty-six was chosen for in-depth investigation. We discuss the appropriateness of solar energy for Thailand context. The diffusion process of PV systems is analyzed on four elements: innovation, communication channel, time and social system. This project is an extreme case as the PV systems and services were provided for free of charge. Even so, there are still some challenges to get acceptance for this sustainable form of energy.

Keywords: Diffusion of innovation; Innovation; Photovoltaic; Rural; Thailand.

1. Introduction

Climate change conditions the transformation process also for developing countries even though they have low historical as well as actual emissions of greenhouse gases. Although having a strong moral position in international negotiations, late coming countries face that the window of opportunity is closing as regards entering upon the classic carbon based path of development and growth. On the other hand, never having been totally locked in on that carbon path may create opportunities for the latecomers. Leapfrogging directly to sustainable technologies could thus be a potentially successful strategy irrespective of the successes in the UNFCCC rounds.

However, transfer or diffusion of new technologies – be they sustainable or not - always take time (we will return to that below). Not the least is that the case in developing countries when costs and alternative use of funds can make acquisition prohibitive for poor people in the countryside. Cultural distances between providers and users as regards what problems the technology is assumed to solve may also contribute to the stickiness in the diffusion process.

To facilitate the introduction of sustainable energy technologies in backward areas, it is thus important to learn about absorption problems, parts of which may be assumed to be related to the technology itself, parts of which may be assumed to be of communicative character.

The objective of this study is to analyze the diffusion of photovoltaic (PV) technology to rural areas in Thailand and also aims to contribute to the learning on how to manage the leapfrogging policy towards sustainable energy solutions in developing countries. The paper analyzes a small-scale PV system project in remote areas of Thailand where the inhabitants did not have access to electricity. We chose an extreme case in which PV systems were provided for free of charge. Thus, the concern on price which is one main bottleneck criteria for using PV system [1] is eliminated. By removing this factor, it should be

assumed that the project could be run without any difficulties. This is proved to be incorrect in this study. The article is organized as follows. Section two provides a brief summary of the research methodology. Section three introduces the theoretical framework which we use diffusion of innovation, institutional theory, absorptive capacity and cognitive distance. Section four contains a discussion on sustainable energy technologies particularly PV in Thailand context. Then we provide descriptive explanation about the project as a background for the next two sections. In section six, the diffusion process is analyzed. We combine all the challenges that we identify in section seven. Finally, the paper ends with conclusion of our research.

2. Methodology

This research is a single case study. A single case can be used to test, confirm, challenge or extend theories [2]. The analysis may reveal the existence of a phenomenon which may be used to falsify a conjecture [3]. The case study can thus provide insights on probable and maybe contextual mechanisms which – together with knowledge we already have – may provide a reasonable solid ground for policy or management activities. This is the role of the present single case study. This study is basically a qualitative work [cf. 4]. Neither the selection of interviewees nor the collection of data is performed to get representative results. Although the study uses numbers on the scale of 1-10 to capture the interviewees' perception on specific points, they are not used for statistical purpose. The study may reveal extreme opinions which we analyze qualitatively.

The study is focused on a pilot project installing PV systems in 36 rural villages in northern Thailand. This overall project is considered to be the *case*. One specific project in Banhuaygiangnoi village is analysed and defined as a *sub-case* to provide in-depth illustration. The selection of sub-case is based on convenience. Due to limited resources and time, the sub-case is chosen because it is more accessible than other places. Some places can be accessed only on foot after a few hours hike while this place can be accessed by a four-wheel drive car on a very bad conditioned road.

Data are collected through semi-standardized interviews and document analysis. Purposive sampling of respondents is chosen for the interviews with an intention to capture broader group of respondents.The interviewees are officers from eight governmental agencies, field teachers who work under Office of the Non-formal and Informal Education and local people from Banhuaygiangnoi village. The total number of the interviewees is 26. Interview guides are developed in advance in three main formats according to the informants. One format of the interview guide is for officers from eight governmental agencies who are the subjects of the overall case. The second format aims at field teachers who are the subjects of the sub-case. The last one is for the local people from Banhuaygiangnoi village who are also the subjects of the sub-case.

In addition to interview data, we use information from documents. In this paper, documents refer only to written sources which can be official as well as unofficial documents, internal reports or other written papers [cf. 5].

3. Theoretical framework

This is basically a study on technology diffusion. It can also be argued that this is a study of innovation as those who adopt technologies developed by others have to innovate to make the innovation fit with their systems and purposes. For developing countries, this often implies the absorption of innovation that exists somewhere else in the world and becomes adapted to local needs [6].

Rogers gave a concise definition of diffusion of innovations in the following sentence: "*Diffusion* is the process by which an innovation is communicated through certain channels over time among the members of a social system." [7: p. 5]. There are, according to him, four main elements in the process of innovation diffusion namely (a) *innovation*; (b) *communication channel*; (c) *time*; (d) *social system* [7].

As mentioned in the introduction to this section, the *innovation* element in the diffusion process may be underestimated by analysts. There may be many reasons for bad fitness between the new technology and the system it is supposed to penetrate. This was, for example, the case with hybrid corn analysed by Griliches [8]. For many emerging technologies, the reason for slow adoption is simple: they are still not good enough for demanding potential users, more innovation is needed by the technology providers rather than more communication.

The *communication channel* is important in the Rogers' approach. Mass media (e.g. television or newspapers) are usually the fastest and most efficient means to inform a wide audience on an innovation.

In contrast, it is more effective to persuade someone through an interpersonal channel especially if it happens between those with similar background. Diffusion is a social process.

Time is a part of the process and can be further explained into three sub-processes. The first part is an innovation-decision process which is the stage that one passes the first knowledge of an innovation to either adoption or rejection. The second one is the relative earliness or lateness that an innovation is adopted by other individuals. The last stage is the rate of adoption which is measured by the numbers of people that adopt an innovation in the certain time frame.

The last element in the process is the *social system*. It is a set of connected units that are bound to one another to achieve a common goal. The members may range from an individual to an organization. The system is bound by the fact that members cooperate to reach a mutual goal. Within the social system, individuals have different roles. Opinion leaders and change agents are one of the important actors for diffusion process. Opinion leader is individual who can influence others in a desired way. Change agent is individual who influences other people's decision making to go towards change agent's desired way. Opinion leader usually comes from that community while change agent is the external entity who often uses opinion leader to influence other people in the community [7].

Rogers' strong focus on communication, the time element and the social system has made him attractive among marketing researchers [cf. 9]. These approaches are also relevant in our study. In addition, the cognitive aspects of the diffusion process should be considered.

External sources of knowledge are crucial for the innovation diffusion process. Thus the ability to employ external knowledge is a very important component. This ability, in turn, is based primarily on prior knowledge or *absorptive capacity*. The concept of absorptive capacity was first introduced by Cohen and Levinthal and defined as follows: "prior related knowledge confers an ability to recognize the value of new information, assimilate it, and apply it" [10: p. 128]. This implies that all diffusion process requires certain preparedness and is in principle relevant also for individual users as well as organizations and firms. The relation of absorptive capacity to innovation diffusion argument discussed above is obvious: one often has to master the imported innovation/technology to make it fit.

Nooteboom analyzed the impact of *cognitive distance* between technology providers and users in the diffusion process. His argument is, in short, that there is an optimum span of cognitive distance favorable for diffusion: if the span is too large the actors do not understand each other and if it is too small there are not enough incentives for mutual learning [11, 12].

Our case takes place in a certain institutional context and its outcome may obviously depend not only on the technologies and its users but also on those institutions involved. Our study will thus be framed within institutional theory conventionally used by innovation analysts.

Following North we may make a distinction between *organization* and *institution*. The following is his definition of institution: "Institutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction. … Institutions are a creation of human beings. They evolve and are altered by human beings; hence our theory must begin with the individual." [13: p. 3-5]. Institutions possess three basic functions. The first function is to reduce uncertainty and provide information. The second one is to manage conflicts and control cooperation. The last function is to provide incentives [14]. There are many ways to classify different types of institutions. The relevant categorization of institutions suitable for this paper is the distinguishing between *formal* and *informal institutions*. The examples of formal institutions are written laws and governmental regulations while examples of informal institutions are common laws and working norms. The impacts of these institutions are different in each country. Informal ones are less visible and need to be observed through daily behaviour [14].

As for the definition of *organization*, North defined it in the following sentences: "If institutions are the rules of the game, organizations and their entrepreneurs are the players. Organizations are made up of groups of individuals bound together by some common purpose to achieve certain objectives." [15: p. 361]. Organizations include various bodies such as firm, school, regulator [15]. However individuals in organizations do not necessarily have common goals. There are also internal processes within organizations which should be reminded when analyzing them [16].

When discussing institution and organization, it is also important to consider linkages which connect various components. The relevant type of linkage for this paper is interaction linkage between different actors [17]. We separate it to *formal* and *informal linkages*. By saying formal, we mean that it is an established function such as official command and while saying informal, we mean that it is an unofficial link between actors such as personal relationship.

4. Sustainable energy and photovoltaic system for Thailand context

Renewable energy has undoubtedly high potential to meet with rising energy demand in the near future. There are various types of renewable energies. It is necessary to properly appropriate the energy choices. According to the World Energy Council (WEC), the ranking of renewable energy alternatives should be considered by using 3A's principle:

i. availability for continuous supply;
ii. affordable energy;
iii. acceptability especially in terms of environment [18].

The *availability* of solar energy in global level is abundant. The amount of solar energy that reaches earth annually is about 10,000 times more than global energy consumption from fossil fuels, hydropower and nuclear power altogether [19]. In the case of Thailand, there is also no shortage of solar energy. The intensity of solar radiation in Thailand lies between 14.25-23.76 MJ/m^2 [20]. This makes Thailand a good location for utilizing PV systems.

The *affordability* challenge is more complex. Historically prices for producing electricity with PV systems have not been competitive if there are other alternatives. That also means that poor rural people – in Thailand as well as elsewhere - normally find PV systems non affordable. However prices have fallen rapidly during recent decades, not the least since Chinese firms started mass production. In addition there have been innovations in thin film technology and black silicon which will impact the price competitiveness and thus the diffusion process in the near future.

As regards *acceptability*, the basic condition is fulfilled: PV systems converting solar energy to electricity are environmentally friendly and have a very small footprint. As is shown by the struggle – all over the globe – on where to locate (or not to locate) wind turbines, being environmentally friendly is not an enough argument for technology to be acceptable. However, as PV systems are silent and clean and do not dominate the landscape, they are normally accepted by most users – and their neighbours.

Consequently, solar energy is a rational choice of renewable energy for Thailand according to WEC 3A's principles.

5. Project description

The study analyses a project engaged in the diffusion of PV systems to rural areas. The PV systems in focus are stand-alone or off-grid installations designed to be used in remote areas where there is no national grid available. During daytime, sunlight is collected and transformed into electricity. The excess of electricity is stored by using batteries for use at night time [21]. The PV system used in this project is designed and produced by National Science and Technology Development Agency (NSTDA)[1]. Despite the fact that PV systems have been previously developed and utilized elsewhere in the world, when it is utilized in local context in Thailand, it can be considered as an innovation diffused to a different location.

The case is a pilot electrification project in the northern mountainous area in Thailand. The dissemination of the PV technology is done through learning centers located in each village. The learning centers are used as local schools. Social activities are also gathered there[2]. We choose to investigate this project because it aims at sustainable electrification by engaging several governmental agencies. This project is initiated by Her Royal Highness Princess Maha Chakri Sirindhorn arguing that every learning center on the mountain should have access to sustainably produced electricity so that the quality of teaching and learning would be at par to those in towns[3]. At that time NSTDA had research on PV system which could be used in the remote areas[4]. The overall project – of which ours is a case - included the cooperation of eight governmental agencies (considered as organizations) which are:

i. Office of Her Royal Highness Princess Maha Chakri Sirindhorn's Projects (OPSP);
ii. National Science and Technology Development Agency (NSTDA);
iii. Office of the Basic Education Commission (OBEC);
iv. Office of the Non-formal and Informal Education (ONIE);
v. Vocational Education Commission (VEC);

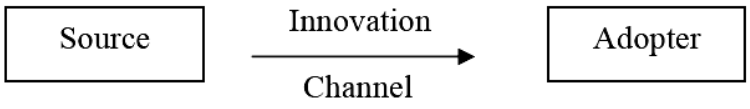
[1] NSTDA (2008). Memorandum of understanding for the pilot project management for photovoltaic system in Thai Phukao learning center of the Sirindhorn royal project.
[2] Information leaflet about learning center project at Banhuaygiangnoi village.
[3] Interview with Phanom Duangthong, OPSP; Sureerat Torsuwan, OBEC; Siranee Imsuwan, ONIE.
[4] Interview with Chatree Tangamatakul, NSTDA; Mali Chansunthorn, NSTDA; Kulwaree Buranasajjawaraporn, DEDE; Anonymous, VEC.

vi. The Institute for the Promotion of Teaching of Science and Technology (IPST);
vii. Department of Alternative Energy Development and Efficiency (DEDE);
viii. CES Solar Cells Testing Center (CSSC).

Each organization is assumed to contribute with their special competence. It starts with the determination of the areas where electrification is needed by OPSP. Then NSTDA provides the system and works in conjunction with IPST to educate users. NSTDA also analyzes the performance of the PV systems. OBEC and ONIE are the receivers of the PV systems. OBEC and ONIE have the same roles but they are responsible for different learning centers. Teachers at learning centers are working under these two agencies. VEC acts as a technical service center for maintenance and fixing problems. Without incorporating knowledge about solar energy and the system in classrooms, this project would not be sustainable as users would not neither know what it is nor how to take care of it. Therefore, IPST's responsibilities include educational media preparation and training session arrangement for teachers so that they can educate their students. DEDE and CSSC are consultants[5]. It is worth noting that this management style may be considered as novel in Thailand context as it is uncommon to incorporate a large number of agencies in a single project.
From November 2007 to December 2009, PV systems were installed in thirty-six learning centers in Tak, Chiangmai and Maehongson which are provinces in the northern part of Thailand[6]. The learning center in Banhuaygiangnoi village is chosen as a sub-case in this study. There are two teachers stationed at the center and the center is supervised by a supervising teacher. In this study, these teachers are considered to be users rather than government officers. This is because their roles are the users of the project not the ones involved in the overall picture of the project. The analysis concerning users is substantially based on the investigation of this sub-case.
It should be noted that two factors may be assumed to favour the result of this project:
i. Due to high popularity and highly respected nature of the royal family in Thailand, the royal family has a strong position among the potential users of the PV installations. They may be looked upon as a good communication channel and also a crucial institution.
ii. The PV systems are distributed for free of charge. At least in this analysis, prices are of no importance.

6. Analysis of the diffusion process

In this paper, the innovation refers to PV system. The diffusion of PV systems in this study occurs between governmental agencies and rural users. The boundary of the research encompasses all those involved in the project and end users. The diffusion of PV system process can be illustrated in Figure 1.



Source = Governmental agency
Adopter = User
Innovation = PV system
Channel = Pilot PV project

Figure 1. Diffusion of PV system process

From the diagram, the innovation is PV systems. The source of innovation is a governmental agency that produces PV systems. The adopters are users in the remote areas in Thailand. The channel, in which the innovation is transferred, is a pilot PV project.
The analysis is done around the four elements of diffusion process namely innovation, communication channel, time and social system [7].

[5] NSTDA (2008). Memorandum of understanding for the pilot project management for photovoltaic system in Thai Phukao learning center of the Sirindhorn royal project.
[6] Institute of Solar Energy Technology Development (2010). 2009 Progress report for the pilot project management for photovoltaic system in Thai Phukao learning center of the Sirindhorn royal project.

6.1 Innovation

In this project, the PV system designed to produce electricity in hot and humid climate is manufactured by NSTDA[7]. This is taken to be the innovation. On the question on their needs for electricity, all of the users say that they need electricity and that they want to have electricity via solar energy. We interpreted the answers that they appreciate the value of electrification which results in the feeling of preservation and need to maintain the technology so that its performance would remain at the maximum level for as long as possible. Moreover, in order for the users to cooperate, they need to be highly motivated to adopt the innovation and – at least subjectively – be in need of electricity.

Furthermore, as regards the complexity of this innovation the adopters were asked to rate the system on the scale of 1-10 ranging from 1 "very difficult" to 10 "very easy". All rank the complexity at a full scale point of 10. This shows that there is a fit between the absorptive capacity and the technology and that the training sessions and training media prepared by NSTDA and IPST are of fine quality and adequate for practical use. Since this project aims at sustainability, users' understanding of the system is definitely necessary.

The benefit of PV systems, mentioned by several users, are lighting and receiving news from outside the village by watching television. By having the light in the evening, it makes an educational programme for adults possible. Adults need to do agricultural and other outdoor work during the day. Thus they only have time to study in the evening. Without lighting, they would not have had this opportunity[8]. Many respondents mentioned a new activity resulting from electrification that people in the village come to watch television at the learning center in the evening. They can receive news from outside the village.

6.2 Communication channel

The second element in Rogers' typology is the existence and character of the communication channel. Communication channels are both via mass media (e.g. newspapers) and interpersonal channels. Interpersonal channels are – in this project - the important communication channels for adopters. For example, the teachers that we interviewed from Banhuaygiangnoi learning center have very positive views and are very satisfied with this PV system. They said that they would recommend other teachers and urge them to use this innovation in other localities. Field teachers from different learning centers usually have small cognitive distance because their social and education background and also their duties are rather similar. This informal communication channel might be an effective way to distribute news about this innovation. Mass media channels are important in advertising the innovation so that audiences know about the existence of such innovation. Anyhow, the evaluation is usually based on interpersonal channel which can be communicated among users.

Moreover, it was revealed that communication was facilitated by using an OPSP agent. Even prior to the PV project, OPSP works directly with local people and they also represent the royal family member[9]. Therefore, the formal linkage (between OPSP agent and users) together with the informal institution (connection to the royal family), OPSP is a good communication channel for rural inhabitants.

One aspect of the communication which lubricates the diffusion process, as illustrated in figure 1 above, is training. Assuming that there is a significant variety as regards the users' prior knowledge about solar energy, training programs have to be adjusted to the absorptive capacity of the various groups of users. Our discussions revealed a high cognitive distance between NSTDA people and the users. The education experts from IPST did not reveal the same cognitive distance. Together with their expertise in teaching, it makes IPST to be the suitable responsible agency for training.

The adopter's views on the training they received were also asked for. They were asked to rate the quality of the training on a scale of 1-10 ranging from poor to excellent and the degree of adequacy of the knowledge acquired from the training sessions on a scale of 1-10 ranging from not adequate at all to highly adequate. All of them rated above 6 which we interpret that they were satisfied with the quality and the adequacy of the training.

However, some interviewees also mentioned that the frequency of training were too seldom[10]. This raised one concern. Considering that this project is fully subsidized by the government, how training could be organized and financed if the project done by private sector is an issue.

[7] Interview with Chatree Tangamatakul, NSTDA.
[8] Interview with Boonrat Krisri, Teacher.
[9] Interview with Phanom Duangthong, OPSP.
[10] Interview with Sureerat Torsuwan, OBEC; Anonymous, VEC.

6.3 Time

Considering the third element -time-, the project had – at the time of this study - already passed the first stage or innovation-decision process. Our case study includes only those already dedicated, i.e. those who have joined the program. At the time of this research, it is at the second stage. In the rural areas, the earliness or lateness of adoption is complicated and they are difficult to be measured. Users may want to have PV systems but cannot afford one. Therefore, they need to wait until the systems are provided by the government. The rate of adoption is not studied in this paper.

6.4 Social system

In this analysis, the social system is comprised of governmental agencies as well as users. To be specific, governmental agencies are the change agent while teachers act as the opinion leaders among the users.
To simplify the roles of several governmental agencies, we summarized them in Table 1.

Table 1. Roles of governmental agencies

Agency	Role
OPSP	Searcher of electrification needed areas
NSTDA	Innovator
OBEC	Adopter of PV system
ONIE	Adopter of PV system
VEC	Technical service center
IPST	Education expert
DEDE	Consultant
CSSC	Consultant

One barrier in using PV systems for rural electrification is the lack of cooperation and planning among governmental agencies for rural energy provision. In many countries, one ministry deals with one specific issue [22]. Thailand is not an exception. There are several governmental agencies installing stand-alone PV systems where there is no electricity available. However, these projects are not always managed with sustainability as their main objective. They are sponsored by the government on an annual basis, which means that at the end of the fiscal year, the money runs out and there is no after-project-inspection. Therefore, some systems are broken and do not receive any further attention after installations[11]. There is a need for interdisciplinary approach for rural electrification to be sustainable. Thus this paper illustrates a pilot project done by a group of governmental agencies.

The role of the royal family for project outcome motivates some reflections. It is our impression that it is beneficial for collaboration in this project. In the context of Thailand, encouragement from the royal family members is of great importance especially for projects concerning rural areas. Also external collaboration may have increased by having a royal family member behind the project. An example was the donation of inverters by a private company[12]. This is probably the major informal institution which is contributing greatly to the progression of this project. This institution is very specific to Thailand context as most Thais are extremely loyal to the royal family.

The role of users – actual as well as potential - in the social system of this diffusion process is crucial. Their involvement leads to the creation of more precious innovation and better adoption. Thus including users in the early stage and also keep their active roles are necessary for such diffusion to be successful [23]. In this paper, users are regarded as one of the organizations. This project clearly includes users in the diffusion of innovation process. Without collaboration from users, the diffusion of PV system to rural areas would not have been achieved. In order for the users to cooperate, they need to be highly motivated to adopt such innovation. This could be reflected through the users' needs as they would not have collaborated if they did not want to have electricity. From the beginning of the project, it aims at sustainability with user participation. Therefore, users are involved. Unlike previous projects done by other governmental agencies which install the system by technicians, this project let the local users install the system by themselves[13]. Such an endeavor reveals the authentic effort of the users which reflects back to their real needs.

[11] Interview with Phanom Duangthong, OPSP; Chaimongkon Senasu, VEC; Chatree Tangamatakul, NSTDA.
[12] Interview with Kulwaree Buranasajjawaraporn, DEDE.
[13] Interview with Chatree Tangamatakul, NSTDA.

In relation to the functions of institutions described under the theoretical framework, all three functions can be observed in this case. Having written agreement in the memorandum of understanding provides clear and concrete information on what tasks that agency is responsible for. By following the memorandum of understanding and also using the relations (formal linkage) between organizations, cooperation can be controlled. The last and very specific function for this case is the existence of royal family support which provides incentives for the overall project.
Considering the large number of organizations involved in the project, the issue of coordination among various agencies becomes a crucial one. The respondents were interviewed about the collaboration among the eight governmental agencies involved. The degree of collaboration among people in this project is rated by a scale of 1-10, from 1 "no collaboration at all" to 10 "full collaboration". The individual scores range from 5.5 to 10. This may be interpreted that the respondents believe the collaboration of this project is satisfactory but not outstanding.
The following section discusses challenges on the collaboration within the social system and also general challenges on this diffusion process.

7. Constraints for the diffusion and remaining challenges

Even with two favoring conditions (having a royal family member and free PV systems) as mentioned in section 5, there are still challenges in this pilot project. We group them in the following categories.

7.1 Economic challenge

It is not an uncommon practice that the government initiates a pilot rural electrification project to gain hands-on experiences before enlarging it [24]. However, the financial scheme was not tested in this pilot project. We are aware that finance is an important part for rural electrification which can create bottleneck for wider diffusion. A concern on price was also mentioned by several governmental agents[14]. This specific PV system is locally produced. However, it was done at lab scale which results in higher price compared with industry scale. Moreover, there is a lack of researches within Thailand in the field of PV. Therefore, it needs to be imported which adds up the cost[15]. Anyhow, this project was made possible because the users do not have to bear any cost. If the project aims at wider scale adaptation of PV systems, the government may need to incorporate other bodies such as industry, donors and financial institutions. Experiences may be learnt from other countries such as fee-for-service scheme in South Africa [24]; using local production with technology transfer from university and user participation in Bolivia [25] and financial arrangements in terms of government subsidy, investment from private sector and credit from financing institutions in Nepal [26].
Even with government funding, the project as a whole is - as we can see - underfinanced. More importantly, each agency uses its own funding for its share of the joint project. There are thus important imbalances in the financial situation between agencies creating severe bottlenecks. A concrete outcome of this financial imbalance is that VEC could not send personnel for maintenance as often as they previously agreed upon in the memorandum of understanding[16]. A possible solution could be to set up a total budget for the project and distribute it to all agencies. Governmental regulation (formal institution) to control proper use of money is also necessary so that the money will be used in the most appropriate way.

7.2 Social challenge

A new phenomena resulting from electrification, as revealed in our interviews, is that young people want to leave the village because they saw from television alternative modern life in the cities. This results in having many elderlies left behind[17]. In contrast, a study on the electrification in Romanian hamlets predicted that development caused by electrification would stop young people leaving to the city [27]. How electrification affects rural community in both short and long run may be investigated to prevent possible social problems.

[14] Interview with Kulwaree Buranasajjawaraporn, DEDE; Chatree Tangamatakul, NSTDA; Chamnan Limsakul, CSSC; Jaran Sritharathikhun, NSTDA.
[15] Interview with Jaran Sritharathikhun, NSTDA.
[16] NSTDA (2008). Memorandum of understanding for the pilot project management for photovoltaic system in Thai Phukao learning center of the Sirindhorn royal project.
[17] Interview with Rue-Det Wongsa, Teacher.

7.3 Infrastructure challenge

Cooperation is limited and is not performed as frequent as initially agreed. To be specific, teachers at the learning centers do not send performance reports according to what was pre-scheduled and VEC personnel claim that the area is difficult to access. This problem has at least parts of its origin in the remoteness of the areas. Some learning centers are very difficult to access. Far distances and bad roads make it difficult to serve distant localities with qualified staffs. This makes the rural communities being isolated from the town – those in the village do not come to town often and even more seldom vice versa.

7.4 Sustainability challenge

The future of this type of project has high uncertainty. Even though this project aims at sustainability, how to make it self-sustained is still questionable. Without continued support from eight governmental agencies, the project might come to a halt. Since governmental budget is approved every now and then, what would happen to these learning centers after the money runs out is unknown. It risks repeating the failure as other previous projects. How much the government can and need to subsidize such projects before they can run by itself is also a challenge. Moreover, all of the respondents indicate that royal support is one main factor that makes every organization cooperate. How the collaboration would be without the support of royal family is doubtful.

8. Conclusion

Solar energy is a promising choice of renewable energy in Thailand context as well as in many developing countries. It is also suitable to be used to electrify rural areas. The diffusion process of a pilot project which installed PV systems in rural Thailand is analyzed. The innovation is not only PV systems itself but it is also the management of the project that involves various governmental agencies. It was mutually agreed among the respondents that the complication in electrification is not the technology itself but more on how to manage it. Communication of the innovation is shown to be more effective via interpersonal relationship. Training is a major tool that drives the diffusion for sustainable use of PV systems. Effective training was carried out by using education expert rather than technical expert to reduce cognitive distance. The existence of royal family support lubricates the diffusion process as it can be looked upon as a good communication channel for rural inhabitants. At the time of this study, the diffusion is in the second stage. Users and eight relevant governmental agencies are all the major actors or organizations within this social system. The collaboration between the innovation source and the adopter is crucial. For this specific case, the involvement of a royal family member was deemed as a significant institution. However, given all these basically favorable conditions, there are still challenges. Among these are concern on price, social impact, infrastructure and sustainability. The policy conclusion which may be drawn from this single case is that the transformation to sustainable forms of energy in rural areas of developing countries may take time and need a lot of efforts. Even if the energy is provided for free of charge, there may be switching cost. The cost is not necessarily in economic terms but it can also be psychologically e.g. changing habits. Anyhow, experiences from this project are valuable as it shows good practices and also show what could have been improved.

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References

[1] Poullikkas A. Technology and market future prospects of photovoltaic systems. International Journal of Energy and Environment. 2010, 1(4), 617-634.

[2] Yin R.K. Case study research: Design and methods. 4th edition. Sage Publications, 2009.

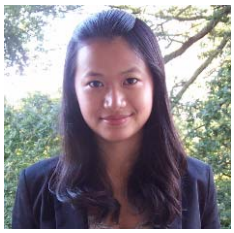
[3] Popper K. Conjectures and refutations. Routledge, 2002.

[4] Flick U. An introduction to qualitative research. 4th edition. Sage Publications, 2009.

[5] Caulley D.N. Document analysis in program evaluation. Evaluation and Program Planning. 1983, 6(1), 19-29.

[6] Lundvall B.Å., Vang J., Joseph K.J., Chaminade C. Innovation system research and developing countries. Chapter 1 in Handbook of innovation systems and developing countries: Building domestic

capabilities in a global setting (Ed. Lundvall B.Å., Joseph K.J., Chaminade C., Vang J.), pp. 1-30, Edward Elgar Publishing, 2009.
[7] Rogers E.M. Diffusion of innovations. 5th edition. Free Press, 2003.
[8] Griliches Z. Hybrid corn and the economics of innovation. Science. 1960, 132(3422), 275-280.
[9] Kotler P. Marketing management: Analysis, planning, implementation and control. 9th edition. Pentrice Hall, 1997.
[10] Cohen W.M., Levinthal D.A. Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly. 1990, 35(1), 128-152.
[11] Nooteboom B. Inter-firm alliances: Analysis and design. Routledge, 1999.
[12] Nooteboom B. Inter-firm collaboration, learning and networks: An integrated approach. Routledge, 2004.
[13] North D.C. Institutions, institutional change and economic performance. Cambridge University Press, 1990.
[14] Edquist C., Johnson B. Institutions and organizations in systems of innovation. Chapter 2 in Systems of innovation: Technologies, institutions and organizations (Ed. Edquist C.), pp. 41-63, Pinter, 1997.
[15] North D.C. Economic performance through time. American Economic Review. 1994, 84(3), 359-368.
[16] Hodgson G.M. What are institutions? Journal of Economic Issues. 2006, 40(1), 1-25.
[17] Galli R., Teubal M. Paradigmatic shifts in national innovation systems. Chapter 15 in Systems of innovation: Technologies, institutions and organizations (Ed. Edquist C.), pp. 342-370, Pinter, 1997.
[18] World Energy Council. Energy and climate change. 2007.
[19] Azar C. Emerging scarcities: Bioenergy-food competition in a carbon constrained world. Chapter 5 in Scarcity and growth revisited: Natural resources and the environment in the new millennium (Ed. Simpson R.D., Toman M.A., Ayres R.U.), pp. 98-120, Resources for the Future, 2005.
[20] Waewsak J., Chancham C. The clearness index model for estimation of global solar radiation in Thailand. Thammasat International Journal of Science and Technology. 2010, 15(2), 54-61.
[21] Bradford T. Solar revolution: The economic transformation of the global energy industry. The MIT Press, 2006.
[22] Radulovic V. Are new institutional economics enough? Promoting photovoltaics in India's agricultural sector. Energy Policy. 2005, 33(14), 1883-1899.
[23] Tidd J., Bessant J.R., Pavitt K. Managing innovation: Integrating technological, market and organizational change. 3rd edition. John Wiley & Sons Ltd, 2005.
[24] Lemaire X. Off-grid electrification with solar home systems: The experience of a fee-for-service concession in South Africa. Energy for Sustainable Development. 2011, 15(3), 277-283.
[25] Aguilera J., Lorenzo E. Rural photovoltaic electrification programme on the Bolivian high plateau. Progress in Photovoltaics. 1996, 4(1), 77-84.
[26] Mainali B., Silveira S. Financing off-grid rural electrification: Country case Nepal. Energy. 2011, 36(4), 2194-2201.
[27] Fara S., Finta D., Micu G. Problems of village electrification based on PV systems in Romania: Individual solar home systems for settlements in the Cerna Valley. Renewable Energy. 1998, 15(1-4), 519-522.



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