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Best Management Practices for Sustainability in a Small-Scale Community Renewable Energy: Sathya Sai School Thailand

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Abstract

Organizations working towards standardization have defined universal standards for Best Management Practices (BMPs) for renewable energy (RE) projects. However, these universal standards are better suited to large-scale than small-scale projects such as community renewable energy (CRE) projects. Methods used by CRE projects to achieve BMP status remain to be determined. This paper aims to present various aspects of BMPs for small-scale CRE projects by emphasizing practices that are unrestricted, simple, and adaptable to the surrounding environment, and that will eventually lead to sustainability in the community. The case study involves RE projects at the '*Sathya Sai School Thailand*,' an education-based community which has a community-like organizational management. The community implements CRE projects for educational-awareness program and to serve their energy needs, starting with micro scale in the community which then will impact on the reduction of climate change crisis at global level. The methodologies used for initial assessment of the involvement of residents and stakeholders, attitude of residents towards CRE project management, and attitudes towards the benefits of CRE project management included (1) field research (i.e., field observations and key-person interviews) and (2) a preference questionnaire. The results identify strengths and weaknesses of CRE project management, and are used to evaluate whether CRE project management constitutes a BMPs by using *'The scale and sustainability score sheet'* tool.

Moreover, recommendations for CRE projects to achieve BMPs status for sustainable community RE are generated from synthesis of sustainability ratings of CRE project management and integration of BMPs theory with the gaps and weaknesses of CRE project management. In conclusion, solutions focus on *'actual problem-based solving approach'*, understanding CRE project management problems and sustained practices by community residents are at the core of BMPs. Experiences can be shared by exchanging RE knowledge among academic and professional networks, and this exchange may improve the suitability of REs in relation to dynamic changes in environmental conditions.

Keywords: Best Management Practices (BMPs); renewable energy; community renewable energy (CRE) projects; Sathya Sai School Thailand; self-sustainability; sustainable community renewable energy; climate change mitigation; sustainable development

Introduction

Access to energy is critical to sustainable development [1]. Currently, approximately 1.2 billion people (i.e., 20% of the world's population) have no access to electricity, which impacts the fulfillment of their basic modern life. Thus, future energy demands are expected to increase. Moreover, conventional fossil-based energy accounts for 66% of total greenhouse gas (GHG) emissions [2]. To limit global warming to two degrees Celsius above pre-industrial levels, global GHG emissions must be reduced to half of the 1990s levels by the middle of the century [3]. Adopting renewable energy (RE) has quickly emerged as an important solution to mitigating climate change [4]. Consequently, RE generators have spread across many countries. Recent estimations indicate that RE provided 12.9% of total primary energy supply in 2008 [5] and accounted for 22% of the world's total energy consumption in 2015 [6]. In addition, RE has potential to provide increases that can meet up to 50% of global energy demand by 2050 [7].

Thailand also considers RE as a crucial and urgent issue. Thailand's 11th National Economic and Social Plan (2012-2016) prioritizes RE for sustainability as a key issue; this is also aligned with the 8th National Research Policy and Strategy (2012-2016) [8]. Therefore, RE projects in Thailand have been supported by different agencies that seek to create energy security, reduce energy shortages, reduce GHG emissions, and reduce the cost of importing energy from other countries [8]. However, the involvement of these actors is associated with different strategies, interests, and approaches for management. Hence, the effectiveness of potential management must be demonstrated via an objective metric and must have the potential for replication by other organizations. Moreover, RE projects, activities and strategies should function effectively and produce successful outcomes that have long-term sustainable impacts as described by Best Management Practices (BMPs) [9]. Nevertheless, the universal standards for BMPs of RE projects are suitable for large-scale projects but cannot be readily adapted to every context and project; in particular, they are unsuitable for small-scale Community Renewable Energy (CRE) projects.

Hence, it is essential to determine BMPs for CRE projects to help improve quality of life for people in the community and to enable sustainable self-reliance with the RE community. This study focuses on exploring **how CRE projects can achieve BMPs for sustainable CRE,** using a small-scale community renewable energy in Thailand as a case study. *Sathya Sai School Thailand,* which implements education-based activities through a community-like organizational management, was selected for this study. The rationale for selection of this community is as three- fold: (1) The community has an interest in the significance of RE and self-sustainability; (2) The community already implements CRE projects under its educational-awareness program and to serve its own energy needs; (3) The community is well-known in Thailand as a model community. Therefore, if BMPs can be successfully adopted and implemented in this study, it could be used as a basis for wider adoption to improve management and efficacy of CRE projects worldwide.

Methodology

The methodology for the study comprises two parts.

1) Initial assessment of CRE management and practice. This part is composed of two surveys:

a) Field research (i.e., field observation and key-person interviews) was used to understand in-depth information about CRE projects and technology, site characteristics, population and cultural identity of the community, and community participation methods.

b) A preference questionnaire was used to gather information about community residents' attitudes towards CRE project management and attitudes towards the benefits of CRE project management. The questionnaire was distributed to community residents aged between 13 and 60 years

old (a total of 170 residents). Questionnaires were completed by 170 respondents.

A qualitative comparative analysis between energy management theory and findings from a) and b) was conducted to identify strengths and weaknesses identified by communities managing CRE projects.

2) CRE project management evaluation. This part aims to evaluate whether CRE project management constitutes a BMPs by using *'The scale and sustainability score sheet'* tool.

The data were collected from CRE projects during June 10 – 15, 2013.

Results and discussion

1) Study area

1.1) CRE projects and technology

The community implements CRE projects to serve their energy needs as follows:

- Electricity generated from solar photovoltaic (PV) project, comprising 24 solar PV panels. A multicrystalline solar cell type is used with total installed capacity of 5.25 kW (Kilowatt);
- Electricity generated from a wind energy project; two 20 W (watt) turbines are considered in this study;
- Cooking gas from a biogas project, which includes an anaerobic digester with a production capacity of 0.3-0.5 m^3 gas/m^3 digester volume per day; and
- Transport fuel from a biodiesel project, which includes a production capacity of 4,950 liters/year.

1.2) Site characteristics

The study area is located in Lopburi Province, Thailand. The outcrop area is approximately 100 acres (300 *rai*). Lopburi Province is located in the central region of the country, where average annual solar radiation is in the range of 5-5.3 kWh/m^2 with approximately 5 hours of sunlight per day or 1,825 hours per year. Average daily wind speed is approximately 0.5 m/s relative to 7 m. height, equivalent to approximately 1 mph or 1 knot. In recent years, the maximum sustained wind speed has reached 10.27 m/s, equivalent to approximately 23 mph or 20 knots [11]. The location and total installed capacity of each CRE project are shown in Figure 1.

1.3) Population and cultural identity of the community

With a population of approximately 350, the community has a community-like organizational management with a strong focus on education. The community's head, who was involved in setting the community vision, stressed that community members are trained to become people of good character, embodying honesty, civic duties, and the values of peace, love and non-violence. The goal of the community's management is to create a self-sufficient and sustainable community. In addition, residents are guided by principles that influence their thoughts and perspective. In particular, the residents are encouraged to always themselves two questions before engaging in any activity: "Is what I am going to do good for me?" and 'How will what I am going to do help everyone else?" [12]. Therefore, participation of residents in CRE projects is promoted via awareness-raising and the realization of RE values.

1.4) Community participation methods

Interviews with key members of the community elucidated that community participatory methods promote awareness of the importance of RE and manage CRE projects in the style of education-based communities in which RE knowledge is integrated into the community structure. This integration was accomplished as follows:

- an education-based community with an RE curriculum for residents that included RE courses for residents starting at age 13;
- educational activities in which residents participated in a study trip to the Royal Initiative Project, a biogas project at Chitralada Villa, Dusit Palace, Bangkok;

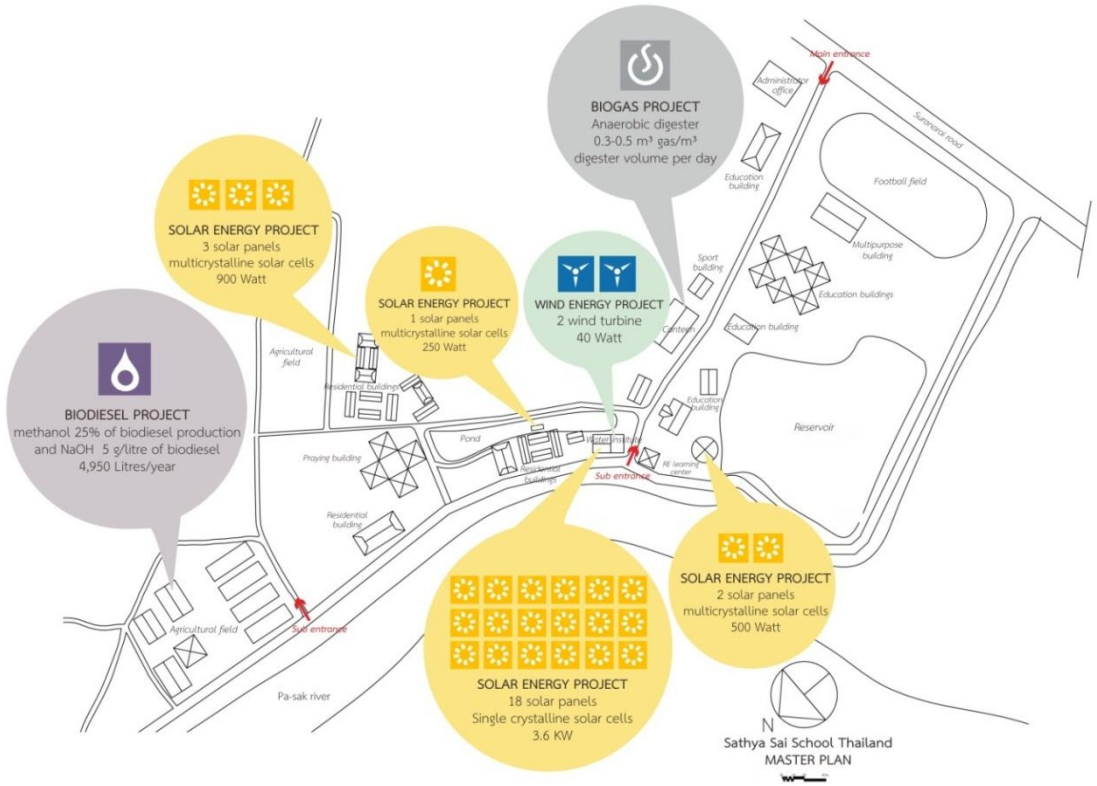

Figure 1 Location and total generating capacity of each CRE project

- working groups of staff that contributed organic waste to produce biogas; and
- community meetings that allowed for discussions and comments regarding CRE projects.

The level of community participation in each RE project exceed 50% (See Figure 2). In addition, CRE projects received support from stakeholders such as the private sector and government agencies including the Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, which provided technical knowledge and equipment. Moreover, the integration of RE knowledge into community activities enabled a strong RE knowledge base among community members and allowed them to share that knowledge with the wider society. This endeavor began with a particularly determined community director who worked to increase the awareness of community members for the climate change crisis and encouraged them to participate in climate change mitigation; primarily by using RE.

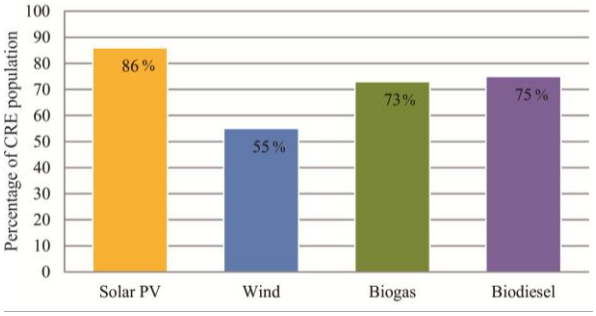

Figure 2 Proportions of the community that participate in CRE projects

2) Attitudes of residents towards CRE project management and attitudes towards the benefits of CRE project management

2.1) Attitudes of residents towards CRE project management

A preference questionnaire was designed to gather information on the residents' attitudes and satisfaction related to increasing the sustainability of CRE projects. Questionnaires were distributed to community residents aged between 13 and 60 years old (i.e., a total of 170 residents). The ques-

tions regarding satisfaction with CRE project management addressed the following topics:

- Location of CRE projects
- Safety of CRE project production
- Readiness of equipment and personnel
- Contributions received from stakeholders
- Public relations for CRE projects
- Implementation of CRE projects

Results from 170 respondents to the preference questionnaire were then analyzed and presented as radar charts (shown in Figure 3).

The radar charts in Figure 3 indicate a high level of satisfaction with CRE project management, categorized mostly at the levels of 'very satisfied' and 'satisfied.' An exception occurred with respect to the *'Safety of CRE projects production'* category. The residents were satisfied with the solar PV project (57%), wind energy project (55%), and biogas project (48%); however, satisfaction was only at a medium level for the biodiesel project (41%). Furthermore, results related to satisfaction with *'Readiness of equipment and personnel'* revealed that satisfaction with the solar PV project (55%) and biogas project (47%) bar were at the 'very satisfied' level, whereas satisfaction with the wind energy (52%) and biodiesel projects (37%) was at a medium level.

The results indicate that the residents' attitudes toward CRE project management were generally very positive. However, residents also realized the limitations of each project. For example, wind turbines can generate only a very limited amount of electricity, while the equipment used for biodiesel production was sub-standard, both in terms of safety and cleanliness of the biodiesel plant. The donated biogas generator had a tendency to malfunction and was frequently out of order.

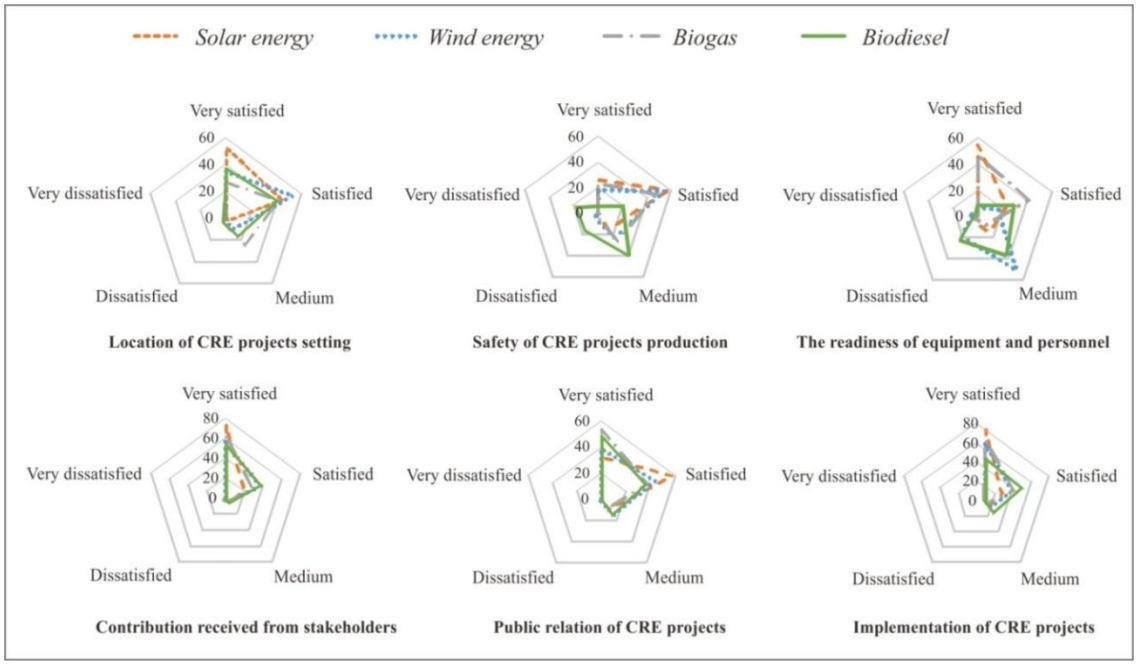

Figure 3 Satisfaction related to CRE project management

2.2) Attitudes of residents towards benefits of CRE projects management

Questions regarding the benefits of CRE project management and satisfaction of the residents were as follows:

- Social benefit: level of understanding of RE production processes
- Social benefit: build a good relationship between residents of the community and their neighbors

- Economic benefit: reduce conventional energy costs
- Economic benefit: create jobs
- Environmental benefit: CRE projects offer solutions to help mitigate climate change crisis

The results of the preference questionnaire are presented as radar charts (Figure 4).

The radar charts in Figure 4 demonstrate a high level of satisfaction with the benefits of CRE project management. Respondents were all 'very satisfied' except for the category '*Social benefit: Level of understanding of RE production processes.'* In this category, satisfaction with the solar PV project (54%) was at the 'very satisfied' level, whereas satisfaction with wind energy (50%), biogas (34%), and biodiesel projects (47%) was only at the 'satisfied' level. These results could be interpreted as an indication that residents needed more information on RE before they were confident with their knowledge of RE production. The community possessed a knowledge management scheme that emphasizes human development, which is consistent with the results of inter- views with community leaders.

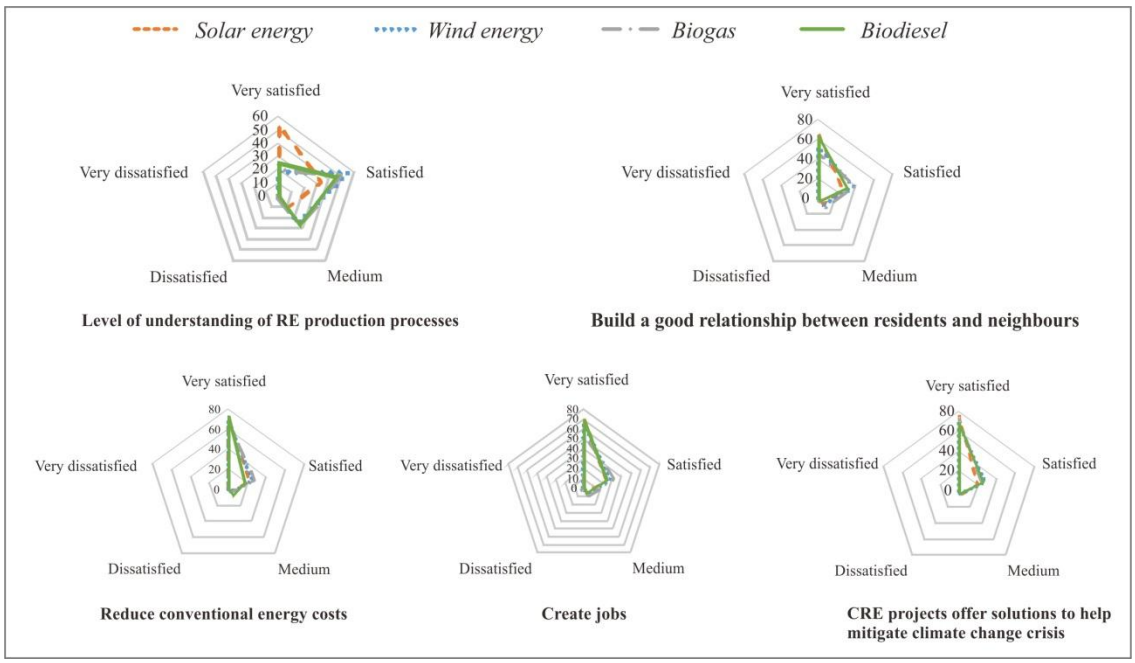

Figure 4 Satisfaction with the benefits of CRE project management

3) Strengths and weaknesses of CRE project management

A qualitative comparative analysis between energy management theory [13] and the overall results was performed to assess the strengths and weaknesses of CRE project management. The results are summarized in Table 1.

4) Sustainability scale of CRE project management: whether CRE projects have Best Management Practices

This section presents an evaluation and synthesis of the overall findings using *'The scale and sustainability score sheet'* tool developed by Spiro (2011). *The Scale and Sustainability Score Sheet* is a tool to examine planning and implementation separately for each sustainability element. The rating and evidence provided by completing the tool should assist the community in determining the scale of sustainability of the CRE project management and identify gaps in planning and implementation [10]. Significantly, the evaluated sustainability rating was used to infer whether current CRE projects can be considered BMPs as shown in Tables 2 and 3.

Table 1 Strengths and weaknesses of CRE project management

Energy management system implementation	Strengths of CRE project management	Weaknesses of CRE project management
Initiating an Energy Management Program	**Social aspects:** 1. Serve as a model of CRE for other communities. 2. Provide an RE learning center in the community for exchanging and sharing knowledge of RE.	-
Conducting an Energy Review	-	**Economic aspect:** There is no official statistic record. However, the financial data implied that RE produced in the community was not adequate for sale and could only reduce small expenses.
Energy Management Planning	-	None of action plan was developed because the CRE projects received donated RE tools and equipment from government agencies that have never measured energy production capacity in the relevant areas or surveyed the actual needs of the community and its residents.
Implementing Energy Management	**Social aspect:** Boost awareness on the importance of RE to stimulate interest and strengthen unity among community members through CRE project activities. **Economic aspect:** Encourage the reduction of conventional energy use, which leads to a reduction of imported energy into the country. **Environmental aspect:** Reinforce RE usage by reducing the use of conventional energy, which causes pollution and climate change crisis. *1. Solar PV project:* reduce CO_2 emissions by 3,061.73 Kg CO_2eq/ year (Emission factor is 0.6093 tCO_2e/MWh) [14] *2. Biogas project:* reduce CO_2 emissions by 55.61 Kg CO_2eq/ year (Emissions factor is 0.4232 KgCO_2eq/ kg LPG) [15] *3. Biodiesel project:* reduce CO_2 emissions by1,957.34 Kg CO_2eq/ year (Emissions factor is 0.3954 KgCO_2eq/ liter diesel, GHG factor of diesel is 3.0982 kg CO_2eq/toe) [16]	**Economic aspect:** Interview with the director of the community stressed that costs of operation and maintenance were higher than the income gained. It was not worthwhile as a business investment. Details are described as follows; *1. Solar PV project:* reduce electricity cost by 37,800 baht/year; however, operation and maintenance costs are 108,000 baht/year. *2. Biodiesel project:* income of 155,220 baht/year; however, operations and maintenance costs are 121,913.75 baht/year. **Technical aspect:** The community lacks personnel who have technical knowledge of RE.
Measurement and Verification	-	Measurement and verification of the knowledge and skills are required to monitor, measure, verify, track, and document energy use and savings.
Management Review	-	Progress reviews or modification of goals and action plans are needed to ensure continual improvement.

Tables 2 and 3 show the evaluation scores for planning and implementation in each category. The total sustainability rating from the evaluation of CRE project management was 67, the planning score was 35, and the implementation score was 32. The results reveal that CRE project management was at a medium level of sustainability (i.e., 67/100). However, the narrow gaps within each category and between planning and implementation reveal that the community had mastered the practical aspects of management because the community was able to implement projects from plan to practice. In conclusion, the results implied that CRE project management could achieve BMP status. If the community has a comprehensive plan in place in which all stakeholders are owners and the three pillars of sustainability - social, economic and environmental - have been fully incorporated, the CRE projects will achieve a high level of sustainability and meet the standards of BMPs.

Recommendations for CRE projects to achieve BMPs status for sustainable community renewable energy

The recommendations are based on a synthesis of sustainability ratings regarding CRE project management as shown in Section 4 and integrate BMPs theory with the gaps and weaknesses of CRE project management as shown on Table 1 Section 3

BMPs was explained by the Renewable Energy Action Team of the California Energy Commission, *"BMPs are recommended practices (or combined practices) determined to provide the most effective, environmentally sound, and economically possible mean of managing a project or facility and addressing the impacts."*[17] Moreover, 'Best' is related to the particular needs or purposes and specific site characteristics to be addressed; it is helpful to identify and classify BMPs according to where they are most effective.

The results of Section 4 suggest that CRE project management in the community could achieve BMPs status. However, there are gaps and weaknesses, particularly in the economic and technical aspects of CRE project management as shown in Table 1, Section 3. Therefore, to ensure CRE projects avoid unintentional negative impacts and allow them to develop effective RE implementation, the recommendations which will drive the progress towards achieving BMPs status in the field of sustainable CRE are focused on the ***'actual problem-based solving approach.'***

The recommendations for CRE projects to achieve BMPs of sustainable CRE from the case study of *Sathya Sai School Thailand* are described as follows:

1) Social aspects

1.1) Promote insight into RE knowledge among residents

- There should be continuing development of knowledge related to RE. Additionally, technical solutions in the 'RE Handbook', which is consistent with the culture of the community, should be published and updated regularly.
- Establish a renewable energy learning center that reflects the identity and culture of the community to motivate and serve as a role model for other communities.
- Promote real community participation.

1.2) Recognize CRE projects

1.3) Consider and comment on CRE projects participation in implementation and operation of CRE projects; sharing ownership of CRE projects

1.4) Participate in the evaluation, extension, and expansion of CRE projects

1.5) Create long-term, high quality jobs and skills for undergraduates; support scholarship for community residents in RE-related fields, and encourage them to work on CRE projects in the community after graduating.

Table 2 Rating of sustainability of CRE project management at the Sathya Sai School Thailand (excerpted by author from Spiro, 2011)

SCALE & SUSTAINABILITY SCORE SHEET

To what extent have the following elements been incorporated into your program or practice?

	SUSTAINABILITY ELEMENT	(P)	(I)	Total P + I		Evidence for the Rating
I. LAWS, REGULATIONS, POLICIES						
a.	Supportive laws or regulations in place	3	3	**6**	(P)	From Thai renewable energy policy
					(I)	From key-person interviews
b.	Institutionalized outcomes of the change (i.e., procedures, position descriptions, curriculum requirements)	2	2	**4**	(P)	From key-person interviews
					(I)	From key-person interviews
	I. AVERAGE SCORES FOR CATEGORY	**3**	**3**	**5**		
II. STAKEHOLDERS (Key individuals)						
a.	Key stakeholders engaged	4	5	**9**	(P)	From key-person interviews
					(I)	From field observation
b.	Little active opposition	3	3	**6**	(P)	From key-person interviews
					(I)	From key-person interviews
	II. AVERAGE SCORES FOR CATEGORY	**4**	**4**	**8**		
III. EXTERNAL PARTNERSHIPS (Key groups or organizations)						
a.	Key organizations engaged	4	4	**8**	(P)	From key-person interviews
					(I)	From field observation
b.	Key organizations perceive the program or practice as furthering their own goals	4	4	**8**	(P)	From key-person interviews
					(I)	From key-person interviews
c.	Union contracts support the program or practice	5	5	**10**	(P)	From key-person interviews
					(I)	From field observation
	III. AVERAGE SCORES FOR CATEGORY	**4**	**4**	**9**		
IV. INTERNAL ORGANIZATIONAL CAPACITY						
a.	Organizational goals furthered by the change	4	4	**8**	(P)	From key-person interviews
					(I)	From key-person interviews
b.	Well-defined procedures and systems for implementation	3	2	**5**	(P)	From key-person interviews
					(I)	From field observation
	IV. AVERAGE SCORES FOR CATEGORY	**4**	**3**	**7**		
V. HUMAN CAPITAL						
a.	A clear and legitimate procedure of succession for those leading the effort	5	5	**10**	(P)	From key-person interviews
					(I)	From key-person interviews
b.	Staff with the skills and knowledge to implement the new program or practice	2	3	**5**	(P)	From key-person interviews
					(I)	From field observation
c.	An institutionalized system for training personnel in the skills needed by the program or practice	3	3	**6**	(P)	From key-person interviews
					(I)	From key-person interviews
	V. AVERAGE SCORES FOR CATEGORY	**3**	**4**	**7**		

Table 3 Rating of sustainability of CRE project management at the Sathya Sai School Thailand (excerpted by author from Spiro, 2011) *(continued)*

SCALE & SUSTAINABILITY SCORE SHEET

To what extent have the following elements been incorporated into your program or practice?

	SUSTAINABILITY ELEMENT	(P)	(I)	Total P + I		Evidence for the Rating
VI. FUNDING						
a.	On-going funding from diversified sources	2	2	**4**	(P)	From field observation
					(I)	From field observation
b.	Coordination of several funding sources to support the new program or building in the new program or practice within existing programs	3	1	**4**	(P)	From key-person interviews
					(I)	From field observation
c.	Cost neutral strategies (reallocation of resources to the new program or practice including cutting funding to programs that are not working well)	1	1	**2**	(P)	From key-person interviews
					(I)	From key-person interviews
	VI. AVERAGE SCORES FOR CATEGORY	**2**	**1**	**3**		
VII. CULTURE						
a.	Program or practice furthers existing values and norms	5	5	**10**	(P)	From key-person interviews
					(I)	From field observation
b.	Favorable attitudes toward the new program or practice	5	5	**10**	(P)	From key-person interviews
					(I)	From field observation
	VII. AVERAGE SCORES FOR CATEGORY	**5**	**5**	**10**		
VIII. CONTINUOUS IMPROVEMENT (Formative Evaluation)						
a.	Continuous gathering of data to support the achievement of the change goal	1	1	**2**	(P)	From field observation
					(I)	From field observation
b.	Provisions for monitoring, learning lessons and consequently making mid-course corrections	2	1	**3**	(P)	From key-person interviews
					(I)	From field observation
	VIII. AVERAGE SCORES FOR CATEGORY	**2**	**1**	**3**		
IX. COMMUNICATIONS						
a.	On-going communications mechanisms including use of media and public relations	5	4	**9**	(P)	From key-person interviews
					(I)	From key-person interviews
b.	Transparency of progress to all constituencies	5	5	**10**	(P)	From key-person interviews
					(I)	From key-person interviews
	IX. AVERAGE SCORES FOR CATEGORY	**5**	**5**	**10**		
X. EVALUATION (Summative)						
a.	Assessment of the program or practice's accomplishments versus planned outcomes after a specified time period	5	3	**8**	(P)	From key-person interviews
					(I)	From field observation
b.	Identified lessons learned	3	2	**5**	(P)	From key-person interviews
					(I)	From field observation
	X. AVERAGE SCORES FOR CATEGORY	**4**	**3**	**7**		
	SUSTAINABILITY Total (P & I)	**35**	**32**	**67**	*(out of 100)*	
	Total	(P)	(I)	(P+I)		

2) Environmental aspects

2.1) Manage waste from RE production processes efficiently, with guidance from specialists.

• ***Biogas***: sanitized compost and nutrient-rich liquid fertilizer should be utilized for sustainable agriculture projects in the community.

• ***Biodiesel***: wastewater treatment should be performed on contaminated water using potassium hydroxide (KOH) and sodium hydroxide (NaOH).

2.2) Utilize or apply the outputs of RE projects in other projects in the community.

• ***Solar PV project and wind energy project***: electricity generated from the solar PV project and wind energy project should be used for a small system such as an air pump system which is used to oxygenate water during wastewater treatment.

• ***Biodiesel***: should be used to fuel water pumps that are part of the sustainable agriculture project.

2.3) Utilize CRE to meet national, regional and local targets that cover a range of issues from carbon to employment.

3) Economic aspects

3.1) Boost the community's income through land-use zoning by allowing other organizations to use some space in the community for Corporate Social Responsibility (CSR) activities with win-win conditions. Therefore, the organizations must provide various forms of economic value to the community.

3.2) Assign staff to research budgets related to RE and address issues including;

• Apply for funds for R&D into CRE projects.

• Monitor updates and information on budget disbursements by key government agencies.

4) Technical aspects

4.1) ***Solar energy***: Polycrystalline is the most suitable material for solar panels. A comparison between monocrystalline and polycrystalline panels revealed that monocrystalline panels were 3% more efficient, although the cost is approximately 10-15% higher than for polycrystalline-based panels. Therefore, for now, polycrystalline is the better option for solar panel investment.

4.2) ***Biogas***: A polyethylene biogas digester (PBD) is expected to perform better than the donated biogas generator because it uses less space and protects the plant from physical harm. The PBD should be constructed underground, to protect from low night temperatures and during winter. On the other hand, it takes longer to heat up during summer and daytime. The digester positively influences the bacteriological processes because there is no temperature variation between daytime and nighttime [18], and it requires a short construction period and small construction area. The maintenance for the digester is not complicated, and it lasts for approximately 12-15 years.

Conclusion

This study focuses on exploring '**how CRE projects can achieve BMPs for sustainable CRE'**. The case study selected RE projects – a solar PV project, wind energy project, biogas project, and biodiesel project - of *Sathya Sai School Thailand*, a well-known education-based model community in Thailand which has a community-like organizational management. This study used both qualitative and quantitative methods.

The results are organized into four sections. The first relates to the characteristics of the study area. The second comprises an analysis of community participation methods, attitudes of residents toward CRE project management, and attitudes toward the benefits of CRE project management. The third section analyzes the strengths and weaknesses of CRE project management. A qualitative comparative analysis between energy management theory and the overall results was performed to assess the strengths and weaknesses of CRE project management. The main weaknesses of CRE project management were found to lie in conducting an energy review, energy management planning, implementing energy management, measurement and verification, and management review. The fourth section evaluates

the sustainability scale of CRE project management to determine whether CRE projects can be considered as BMPs. The total 'sustainability' rating results revealed that CRE project management was at a medium level of sustainability (i.e., 67/100). However, the community had mastered the practical aspects of management because the community was able to implement projects from plan to practice. The ratings from the sustainability assessment of CRE project management implied that CRE project management could achieve BMPs status. If the community had a comprehensive plan in place in which all stakeholders were owners and the three pillars of sustainability – social, economic and environmental – have been fully implemented, the CRE projects would achieve a high level of sustainability and thereby meet the criteria for recognition as BMPs.

Finally, the key findings are synthesized to provide recommendations for CRE projects to assist them in achieving BMPs for sustainable CRE. The recommendations are as follows:

- Recommendations on social aspects, including; (1) promote RE knowledge among residents; (2) recognize the benefits of CRE projects; (3) consider and comment on CRE project participation during their design and implementation; (4) participate in evaluation, extension, and expansion of CRE projects; and (5) Use CRE projects to create long-term, high quality jobs and skills for undergraduates.
- Recommendations on environmental aspect, including: (1) manage waste from RE production processes efficiently, with guidance from specialists; (2) utilize or apply the outputs of RE projects in other projects in the community; and (3) utilize CRE to meet national, regional and local targets on a range of issues, from carbon to employment.
- Recommendations on economic aspects, including: (1) boost community income through land-use zoning by allowing outside organizations to use some designated space within the community for Corporate Social Responsibility (CSR) activities. In order to ensure mutual benefits, the organizations must specify various forms of economic value to be provided to the community; and (2) assign staff to research budgets related to RE and address emerging issues.
- Recommendations on technical aspects, including: (1) Solar energy, polycrystalline is the most suitable material for solar panels; (2) Biogas, a polyethylene biogas digester (PBD) is expected to perform better than the existing donated biogas generator.

In conclusion, the key concept of Best Management Practices for sustainability in small-scale community renewable energy is ***'actual problem-based solving approach.'*** Other communities can adapt this concept to their own CRE projects. Understanding their own community context, strengths, weaknesses and gaps in each of CRE project will be helpful to identify and classify solutions, under the three pillars of sustainability: social, economic, and environmental, which will help CRE projects avoid creating unintended negative impacts and allow them to develop effective RE implementation. Such understanding can also help improve quality of life and self-reliance within the community.

Recommendations for further research include determining innovative technologies for reducing CO_2 emissions and reducing operational and maintenance costs. In addition, future research could be conducted to evaluate BMPs of RE knowledge management that are offered jointly through educational institutions and corporations. Such management could provide a foundation based on a basic understanding of RE to accelerate RE adoption towards a sustainable future.

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