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Sustainable energy adoption in poor rural areas: A comparative case perspective from the Philippines

M.A.J. Quirapas Franco [a], A. Taeihagh [b,*]

[a] Aquatera Asia Pte Ltd, Singapore
[b] Lee Kuan Yew School of Public Policy, National University of Singapore, Singapore

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ABSTRACT

A growing body of literature recognises the role of local participation by end users in the successful implementation of sustainable development projects. Such community-based initiatives are widely assumed to be beneficial in providing additional savings, increasing knowledge and skills, and improving social cohesion. However, there is a lack of empirical evidence regarding the success (or failure) of such projects, as well as a lack of formal impact assessment methodologies that can be used to assess their effectiveness in meeting the needs of communities. Using a case study approach, we investigate the effectiveness of community-based energy projects in regard to achieving long-term renewable energy technology (RET) adoption in energy-poor island communities in the Philippines. This paper provides an alternative analytical framework for assessing the impact of community-based energy projects by defining RET adoption as a continuous and relational process that co-evolves and co-produces over time, highlighting the role of social capital in the long-term RET adoption process. In addition, by using the Social Impact Assessment methodology, we study off-grid, disaster-vulnerable and energy-poor communities in the Philippines and we assess community renewable energy (RE) projects implemented in those communities. We analyse the nature of participation in the RET adoption process, the social relations and interactions formed between and among the different stakeholders, and the characteristics, patterns and challenges of the adoption process.

Introduction[1]

In the field of sustainable development, there is a growing body of literature and practice that recognises the role of the local participation of end users in the successful implementation of development projects. Such community-based initiatives are widely assumed to benefit communities in terms of additional savings, and increases in knowledge and skills and social cohesion. However, while actual projects are happening on the ground, there is a lack of empirical evidence regarding the success (or failure) of such projects, and a lack of formal impact assessment methodologies to assess their effectiveness, given the actual conditions and energy needs of communities. In addition, most policy interventions that apply community participation mechanisms mainly focus on poverty reduction, while they focus less specifically on adopting technology systems like renewable energy technologies (RETs). These objectives are not mutually exclusive, but, as this paper shows, it would be interesting to know how RETs "enable" communities to achieve sustainable energy.

The most successful cases of community-based energy projects are found in developed countries like Germany and the UK. By contrast, this paper explains how communities participate in the RET adoption process in the context of developing countries, and especially in off-grid, energy-poor island areas. While developing countries promote RET adoption at the national level through renewable energy (RE) targets, large-scale deployment, and market incentives, there is still a gap between national RE efforts and the realities on the ground, i.e., off-grid areas are still dependent on fossil fuels and lack access to sustainable energy sources. We investigate the effectiveness of community-based energy projects in regard to achieving long-term RET adoption in various energy-poor island communities in the Philippines. Using

* Corresponding author at: Lee Kuan Yew School of Public Policy, National University of Singapore, 469B Bukit Timah Road, Li Ka Shing Building, Level 2, #02-10, 259771, Singapore.
E-mail addresses: spparaz@nus.edu.sg, araz.taeihagh@new.oxon.org (A. Taeihagh).

[1] This is an extended and significantly revised version of a draft conference paper by Quirapas and Taeihagh (2021) titled 'Renewable energy adoption in poor rural areas: why communities matter' that was presented at the 5th International Conference on Public Policy (ICPP5) in Barcelona, Spain, 5–9 July 2021.

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theoretical frameworks from public policy, political science and innovation studies, this study underlines the importance of studying the nexus of society, technology and development from multidisciplinary perspectives (Bhattacharyya, 2012a, 2012b; Chase & Woolock, 2005; Genus & Coles, 2008; Lacey-Barnacle et al., 2020; Primc & Slabe-Erker, 2020; van der Waal, 2020; Walker et al., 2010). This paper takes advantage of the expanding field in the social sciences that looks at how political and social actors and institutions shape a society's transition to cleaner energy and RE sources.

Specifically, we provide an alternative analytical framework for assessing the impact of community-based energy projects, as follows. (1) We redefine what "successful" RET adoption means, especially in the context of energy-poor areas. Unlike in agent and structural explanations, we define RET adoption following the relational approach towards technological adoption. This means that RET adoption is seen as a continuous process that co-evolves and co-produces over time. Our analytical lens focuses on the social relations between the agents and structures during the adoption process. (2) We critically assess the role of community participation in achieving successful RET adoption. Drawing on social theory, the central assumption in explanations of why the community-based approach works is that it *enhances or changes the character of a community's social capital, as regards achieving a specific goal* (Chase & Woolock, 2005, p. 6). However, scholars claim that local participation is "neither neutral, morally and inherently good or efficient" in addressing the needs of those participating (Ramalho, 2019). This study presents the benefits and constraints of inducing participation to achieve long-term RET adoption. To holistically assess the effectiveness of community participation in regard to successful RET adoption, we apply an impact assessment to community-based RE projects, to identify the impact on the beneficiaries. By impact assessment we mean the "process of analysing, monitoring and managing the intended and unintended social consequences, both positive and negative, of planned interventions … and any social changes processes invoked by those interventions" (Vanclay, 2003, p. 6). These impacts are assessed through the process of change mapping, where we examine how interventions like community-based RE projects contribute to a series of impacts on the community's RET adoption process. In doing so, we adapt Van der Waal's change mapping methodology, as elaborated more in the subsequent sections.

This paper uses a case study approach, applying various data-gathering tools to collect both primary and secondary data. Alongside a desk review of related studies, reports and publications, fieldwork was conducted in the selected island communities. In-depth key stakeholder interviews, site visits, walk-throughs and community observations were carried out during the fieldwork. To select the cases, we used the typical case approach: this is an inductive approach to case selection that helps researchers to understand broader phenomena and that serves an exploratory function. The typical case for this study is characterised as a rural community with limited or no power supply, composed of low-income households who pay high electricity rates. These communities are disaster-vulnerable and have received – or have existing – RE projects and systems to address their lack of electricity.

In this study, we describe and analyse the nature of participation in the RET adoption process, the social relations and interactions formed between and among the different RET stakeholders, and the characteristics, patterns and challenges of the adoption process.

This paper contributes to the wider literature on community participation (Hossain et al., 2023; Fartash & Ghorbani, 2023; Chase & Woolock, 2005; Haddon, 2011; Walker et al., 2010) by investigating the relationship between participation and RET adoption specifically. In addition to providing and applying a formal assessment framework to assess the effectiveness of community-based RE projects, this paper addresses the need to operationalise what successful RET adoption is, especially from the perspective of communities in developing countries. According to scholars, there remains a lack of clarity regarding actual assessments of what constitutes long-term or successful RET adoption in energy-poor areas, especially in the Global South (Casey et al., 2011; van der Waal, 2020). Assessments of community-based projects predominantly reflect the perspectives of the project implementers, board members and funders, with only a minimal representation of community members perspectives (Bhattacharyya, 2006; van der Waal, 2020). As such, the conclusions in the existing literature may lack insights from community members themselves, which could compromise the validity and neutrality of the findings. Increased project- and context-based explanations and greater information on the impact of a community-based approach in RE, such as information about the "characteristics of the project, site, community, region, and the project development and engagement process", are needed to assess the long-term contribution of such projects (van der Waal, 2020, p. 2). Walker et al. (2010) argue that more holistic, systematic and context-based explanations are necessary in order to assess the effectiveness of community-based RE projects in regard to achieving cleaner and more sustainable energy-driven development within communities (Walker et al., 2010).

The next sections of the paper will be as follows. The Theoretical framework section discusses the theoretical groundings of the study. Here, we present our proposed analytical framework, which combines a participatory framework with the RET adoption process, from a relational perspective. The Methodology section lays out the Social Impact Assessment Framework and the case study approach, which are the main methodologies applied in the study. This is followed by the Results and findings section, which gives the results and findings of the study, followed by our analysis in the Discussion section. Finally, we present our conclusion and policy recommendations in the Conclusions section.

Theoretical framework

This study makes use of theoretical frameworks from political science and the science, technology and society fields to enable a more holistic approach towards RET adoption. The next sections expound on the role of social capital in inducing participation in successful RET adoption, followed by giving a definition of what we mean by successful RET adoption, applying the relational approach to technological diffusion. Finally, we explain our framework for evaluating various community energy projects, using the Social Impact Assessment Framework.

Community participation and RET adoption

The community-based approach (also known as community-led or community-driven development (CDD) or community-induced participation) has its origins in historical notions of participatory governance and prescribes the application of interventions where community participation is induced (Kinn & Abbott, 2014). CDD focuses on enhancing involvement within the community. It "supports efforts to bring villages, urban neighbourhoods, and other household groupings into the process of managing development resources, without relying on formally constituted local governments" (Kinn & Abbott, 2014, p. 1). CDD targets local groups that are on or below the poverty line, encouraging them to become partners in pursuing development while building their institutions and cultivating their resources for their own benefit. The participatory framework is based on the argument that individuals who participate in community decision-making create greater capacity for self-reliance and collective action, also known as "social capital" (Kinn & Abbott, 2014, p. 16). Social capital is defined as an individual's attributes and relationships that augment their ability to solve collective action problems (Ostrom & Anh, 2003). At the community level, social capital refers to the qualities of a social organisation: the norms, networks, and trust that improve a society's efficiency by facilitating coordinated actions (Putnam et al., 1994). Ostrom and Anh elaborate that the forms of social capital are trustworthiness, networks, and institutions (both formal and informal) (Ostrom & Anh, 2003). Social capital is also productive and facilitates spontaneous cooperation. This means that community-based RE projects utilise the community's

social capital to engage its members in sustaining RET adoption.

Following the arguments presented by scholars, it seems that if an RET project has mechanisms that induce community participation, this can lead to successful RET adoption. However, this presents a simplified understanding of the meaning of successful and failed technological diffusion.

RET adoption as a relational approach

While plenty of studies have explored the complexities of community participation, and how it works, the field of scholarship on what technological adoption is, is still growing – especially in the energy field (Kinn & Abbott, 2014). Furthermore, scholars continue to debate the role of agents (e.g., community members) vis-à-vis the importance of structures in explaining successful technological diffusion. Both agent-based and structural-based explanations have their strengths and weaknesses. A systems approach helps navigate the level of analysis in regard to analysing adoption, from the household level to broader social structures and frameworks that are beyond the control of the end users. It gives importance to other stakeholders (project managers, local government officials or non-governmental organisations (NGOs)), interests (public or private), or community institutions (formal or informal) that might affect the decision-making process and implementation of the RE project. An example of this level of analysis is where there is a lack of community financing schemes to maintain or repair the RE system. The systems approach also emphasises the path dependency of the technological system – its ability to continue or operate along a given path, as caused by the previous actions of numerous stakeholders, organisations, or institutions within the system.

This does not mean that the transformation of a technological system can only take place through systemic changes: that is, by overhauling the entire system. From the demand side, specific actions or desires and variations in agents' attitudes or activities can modify the existing structure, if sustained for a long time. While the insights of the systems approach reveal the bigger picture of technological adoption, it comes at the expense of a weak conceptualisation of the agential issues, the conflict and politics involved, and the strategies and dilemmas of individual actors in transformation processes (Genus & Coles, 2008). As such, agential and structural explanations can reveal a spectrum in regard to how agents act within the broader social and institutional contexts (Sovacool & Hess, 2017). Structures impact the behaviour and interactions of citizens, while changes in citizens' attitudes and actions can also affect the structures themselves. Farla et al. claim that technological transition can be studied both at the agent and system levels by looking at "the impact of the strategies, resources, and capabilities of individuals, firms and other organisations and how the changes at the system level feedback into the observed strategies of actor level" (Farla et al., 2012, p. 992).

This paper proposes a complementary and hybrid approach to evaluating the importance of an individual's actions and behaviour, as well as the structural opportunities and constraints affecting successful RET adoption – the relational approach (Rutherford & Coutard, 2014; Sovacool & Hess, 2017). This approach defines long-term RET adoption as a continuous and co-evolving process that is made up of different components: the usage of the physical features of the RETs (hardware), the knowledge and skills of end users in regard to operating and maintaining the RETs (software), and the structures and institutions that sustain the RETs (orgware) across time and geographic scales (Rutherford & Coutard, 2014). These components require a certain fit or appropriateness, in order to co-evolve over time towards successful technology adoption and innovation. The unit of analysis of the relational approach is not solely focused on actors or structures alone, but rather on "heterogeneous configurations with co-evolving elements, and envision agency as structured by routines, rules, habits, and conventions" (Sovacool & Hess, 2017, p. 733).

Community participation and long-term RET adoption

While the economic benefits of community energy projects have been well-studied, the qualitative side has hardly been analysed or formally assessed (van der Waal, 2020). The boundaries of the local impacts of community energy projects remain unclear as current studies lack "sensitive and in-depth" types of assessment and extended project-scale evaluations (Walker et al., 2010). By approaching RET adoption as relational, we are able to see the complexities of social relations between the project implementers and the beneficiaries, as well as the tensions among other community stakeholders, like non-beneficiaries, and other external actors, like local government units (LGUs). We are able to analyse the impacts of RETs on the everyday lives of end users, beyond their economic benefits.

Combining the participatory governance framework and the relational approach to RET adoption, this paper proposes that inducing community participation in development projects (or the community-based approach) works because it creates, shapes, or enhances the different forms of social capital (trustworthiness, networks, and institutions) within the community to achieve a particular form of collective action. These forms of social capital incentivise the formation and strengthening of trust between and among the project implementers and community members, in regard to adopting RET systems. Ideally, community-based RE project implementers will also consider the various contextual variables and pre-existing conditions within the community. Existing norms, beliefs, skills, and community capabilities are among the contextual variables that may impact social capital formation, the establishment of trust within the community, and the RET adoption process.

Successful RET adoption is not only the result of actions or changes in agents' behaviour or systemic changes in a community's structures. According to the relational approach, long-term RET adoption is a continuous co-evolutionary process and a continuous co-production of hardware, software and orgware within the community. It highlights social relations and interactions as critical units of analysis, alongside the actors and systems. Finally, the success or failure of the RET adoption process may impact existing forms of social capital and contextual variables within the community. It can also provide feedback to the project implementers in regard to conducting their future community-based RE interventions.

Fig. 1 shows the proposed analytical framework of the paper.

As shown in the analytical framework above, the "ingredients" of successful RET adoption at the community level lie in two significant aspects: (1) the active involvement of community members in the community energy project (through decision-making, and operating and maintaining the RETs, among others); and (2) the sustainability of the community's involvement in the RET adoption process – that is, their continued usage of the hardware components, the utilisation of software skills to operate RETs, and, finally, their participation in orgware, which is the network of actors and institutions that manage and maintain the RETs within the community. As the community-based approach is highly contextual, there is no one-size-fits-all model for community energy projects.

Methodology

The Social Impact Assessment Framework and change mapping

The purpose of an impact assessment is to establish the perceived chain of cause and effect from the deployment of RETs (intervention) to the impacts (benefits or not) described along the proposed analytical chain mentioned above. Vanclay (2003) defined a Social Impact Assessment Framework as the "process of analysing, monitoring and managing the intended and unintended social consequences, both positive and negative of planned interventions … and any social change process invoked by those interventions" (Vanclay, 2003, p. 1). To

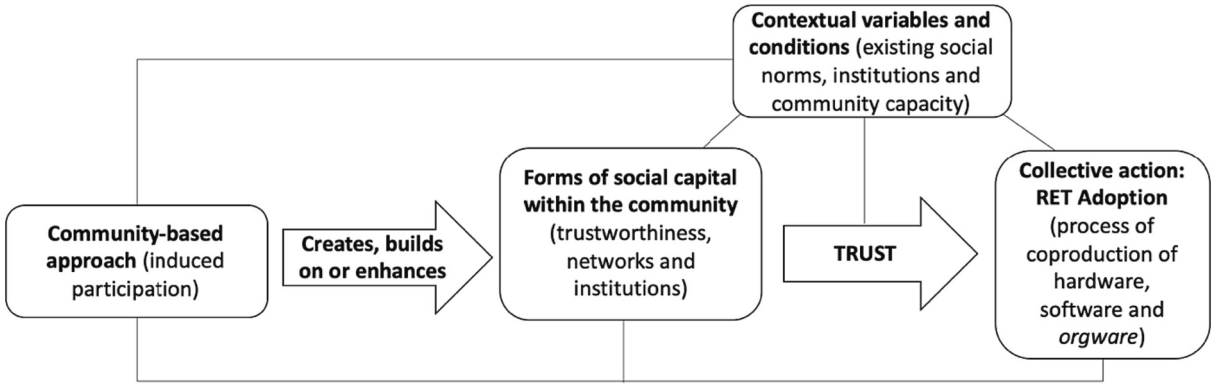

Fig. 1. The proposed analytical framework.

operationalise this framework as a methodology for evaluating community energy projects, van der Waal (2020) utilised the change mapping technique, by which descriptions are created to show how an intervention – that is, a community energy project – has contributed to a series of impacts. These descriptions are called "theories of change" and are defined as the representation of mental models that people have of the change a community leads to. Adapting van der Waal (2020), we used the steps in Table 1 to map the changes for each of our community energy projects.

Case study approach

This study uses a case study approach, including applying various data-gathering tools to collect primary and secondary data. Fieldwork was conducted between August and November 2019 in the selected island communities in the Philippines, alongside a desk review of related studies, reports and publications. In-depth key stakeholder interviews, site visits, walk-throughs and community observations were carried out during the fieldwork.

The case study approach is helpful in theory development, the generation of new evidence and hypothesis testing (George & Bennet, 2004). It "gives a detailed consideration of the contextual factors of a research study which are extremely different from doing statistical studies" (George & Bennet, 2004, p. 19). It is also a useful research approach for identifying new variables and hypotheses for a study heuristically. The case study approach helps explore causal mechanisms and models, and to assess complex causal relations. Although guided by current literature and a theoretical lens, this paper is meant to be exploratory and open to generating new explanations about the topic. (Gerring, 2006).

As mentioned in the introduction, the typical case approach was used to select the cases for this paper. This is an inductive approach to case selection that helps researchers understand broader phenomena and that has an exploratory function. Gerring (2006) argues that analysing a typical case is useful in order to extensively comprehend and explain a particular phenomenon (Gerring, 2006). The typicality of the case can be chosen statistically (according to the mean, median, or mode in a specific dimension and weighted differently) or by factor concerning a causal model of a particular phenomenon that the researcher wants to investigate. This paper examines a particular phenomenon, i.e., community participation in the RET adoption process.[2]

Each community represents a typical case: they are situated in a rural area; they have limited power supply or no electricity at all; and they are composed of low-income households that pay high electricity rates and have received, or currently have existing, RE projects and systems. These communities are also disaster-vulnerable, making it more challenging for RET stakeholders to establish stable on-grid electrical infrastructure that can secure an electricity supply. Despite the existing conditions in these communities, long-term RET adoption may still be feasible if there is a supportive national RE policy framework. However, even with steady economic growth and diversification of the energy supply, 1.26 million people in rural areas of the Philippines are still without electricity and are far from achieving sustainable energy (DOE, 2020). What are the reasons for this? Do these communities have secure energy access, a resilient energy system, and, most importantly, sustainable energy that can benefit their socioeconomic needs? By studying the Philippines' rural communities, one can analyse a typical case of an environment in which there are conducive and supportive conditions, where long-term RE adoption can be expected. However, we found varying levels of RET adoption in the communities studies.

In this study, we describe and analyse the nature of participation in the RET adoption process, the social relations and interactions formed between and among the different RET stakeholders, and the characteristics, patterns, and challenges of the adoption process.

The interviewees were selected through a combination of purposive and snowballing methods. Purposive sampling was helpful for seeking out stakeholders who were essential to the RET adoption process. In total, 65 in-depth interviews were conducted for this research, with the following representatives: 10 RE project implementers, four stewards of

Table 1
Change mapping steps for community energy projects, adapted from van der Waal (2020).

Steps	Definition
1. Community profile	Establish a comprehensive understanding of the project's context, including social, economic and environmental conditions
2. Project profile	Map the conditions the project is seeking to influence and the way in which the desired change is planned to be realised; be aware of the conditions the project can unintentionally influence
3. Creating pathways of change	Create an overview of the activities of the community renewable energy group and the changes to the situation before the RE project became operational; map community members' understanding of how these changes may have happened and how contextual conditions may have affected their occurrence

[2] Gerring (2006) explains that in choosing a typical case, "the researcher has identified a particular outcome (Y), and perhaps a specific X1/Y hypothesis, which she wishes to investigate. To do so, she looks for a typical example of that causal relationship" (p. 92). The puzzle of interest lies within the case where variance of outcome might be seen. By analysing a typical case, researchers can better explore the causal mechanisms at work – either by performing pattern-matching investigation (that is, analysing whether the evidence at hand validates (or not) the prior hypothesis), or by showing that the causal mechanisms at work are different from those previously postulated (Seawright & Gerring, 2008). In this manner, the typical-case approach offers flexibility in regard to explaining specific phenomena of interest.

RE systems, 44 household beneficiaries of RE, five LGU officials and NGO representatives, and two other stakeholders from the business and private RE sectors within the communities. The interviews were transcribed, and the data gathered were categorised into themes and subthemes for content analysis. The content analysis helps reduce and simplify the collected data, measured using quantitative or qualitative techniques.

The case study approach is not without weaknesses. It has been criticised for limitations to the generalisability of the findings as it does not involve a large-N sample. However, it should be noted that case studies can provide depth and thickness of understanding, despite sacrificing the generalisability (Sartori, 1991). It is also important to note that the nature of the community-based mechanisms is highly contextual, and, as such, generalisability remains a challenge. However, this does not mean the findings of this study will not be relevant to other cases. The study results could provide a basis for highlighting best practices or lessons learned in terms of future policy or project interventions involving RET adoption in other rural communities in the Philippines or the region. Similarities might be found between the general characteristics of the rural communities in the Philippines and the conditions of rural communities in Indonesia, especially in coastal areas that are prone to disasters.

Results and findings

This paper investigates different community-based RE projects in the selected rural island communities of the Philippines located in Eastern and Western Visayas: Bantayan, Camotes, Gilutongan, Malapascua and Pangan-an Islands in Cebu; and Alang-alang Municipality in Leyte. The five projects are as follows:

- Project Enkindle is a community-based initiative that seeks to assist typhoon-affected communities by providing energy relief, mainly through solar PV systems. The project started in November 2013 in the aftermath of Typhoon Haiyan.
- Pangan-an Island Solar Electrification Project (PISEP) is the first off-grid RE rural electrification project in the Philippines. It was initiated by the national government to provide 24-h electricity to Pangan-an Island.
- Solar Home System (SHS) is part of the national government's Total Electrification Programme, which seeks to power up off-grid rural and remote areas.
- The Rooftop Solar PV Project is an ongoing community-based RE project organised by the University of San Carlos (USC) – Cebu in Gilutongan, which seeks to establish and sustain rural electrification on the island using RETs.
- Donated RETs are renewable energy systems (mostly small-scale solar PV) deployed in communities as part of one-time donation drives by external organisations or donors.

In addition, self-bought RETs were also included in the analysis to examine households' motivation for buying solar PV on their own.

The sections below describe the step-by-step process of change mapping, conducted as part of the social impact evaluation of each community energy project.

Island community profiles

To understand the impacts of the community energy projects on the long-term adoption of renewables, we provide a comprehensive description of context of each beneficiary community. Table 2 summarises the demographic profiles of each island, the number and types of RETs deployed, and the communities where the selected community-

Table 2
Overview of community profiles.

Community	Types of beneficiary	The main source of electricity	Electricity rate (USD 1 ~ PHP 55.00)	Main source of income	Types of RET deployed	Local community partner/ steward
Bantayan	Households in *Gawad Kalinga* (*GK*) villages	Diesel generator from electric cooperative (24 h per day), but with regular power interruptions	USD 0.18–0.30 per kWh (household) (BANELCO, 2020)	Fishing, fish processing, poultry raising, poultry egg production and tourism	Class 1 (50 W solar PV system with all components stored as small luggage for ease of system deployment and relocation)	NGO (Gawad Kalinga)
Pilar, Camotes	Rural health centre	Diesel generator from electric cooperative (18 h per day), but with regular power interruptions	USD 0.20–0.25 per kWh (household) (CELCO, 2023)	Fishing, fish processing, municipal marine park	Class 1	Barangay officials and a local NGO (The Kindred Nomads)
Malapascua	Households and elementary school	Diesel generator from a private producer (24 h per day), but with regular power interruptions	USD 0.22–0.27 per kWh (household) (Households 1 to 6 in Malapascua, 2019)	Tourism and fishing	Class 1 and 2 systems (Class 2 is a 300 W hybrid RET with solar and wind energy)	Local NGO (Seed4Com)
Alang-alang, Leyte	Households	Geothermal power plant distributed by a cooperative (24 h), but some communities are still not connected	USD 35–120 per month (household) (Households 1 to 12 in Leyte, 2019)	Crop farming and livestock	Class 1	Local university contact
Pangan-an	Individual households and communal facilities	Diesel generator (operational four to six hours per day)	USD 10–25 (for 4–6 h of electricity per day) (Households 1 to 11 in Pangan-an, 2019; PICCD Officials 1 to 3, 2019)	Fishing, ecotourism, shell crafting for a souvenir shop, seashore gleaning, village store retailing, boat servicing and livestock raising	Centralised solar farm; SHS	The national government, Department of Energy, barangay officials and a community cooperative (Pangan-an Island Cooperative for Community Development (PICCD))
Gilutongan	Individual households	Diesel generator (operational four to six hours per day)	USD 10–25 (for four to six hours of electricity per day) (CREST, 2018; Lozano, 2019)	Fishing, seaweed farming, shell collection, live seafood and souvenir vending, and sari-sari stores	Rooftop solar PV in the households, individual SHS and 5 kW donated in school	USC, external donor organisations, barangay officials

based RE projects deployed RETs.

Community energy profiles

The next step is to map the condition the community energy project was trying to influence and the ways in which the desired change was planned and implemented. We provide a summary of each project, their beneficiaries, the types of RETs deployed, other stakeholders' involvement and the status of the community energy projects (at the time of writing). We further expound on the various community-based mechanisms used by community energy projects – that is, the avenues through which beneficiaries were able to participate in the RET adoption process. As mentioned in the previous section, we refer to this as the orgware, or the rules of the game, and as the role each stakeholder plays. Table 3 summarises the community energy profiles, while Table 4 gives an overview of the orgware components of each community energy project.

Creating a pathway of change

The different community-based RE projects brought positive impacts to the island communities. Their main objective was to give the communities access to a clean, renewable and alternative energy source, whether by operating, managing or owning the RETs (Abundo, 2019; Enkindle., 2015; L.O., 2019; PISEP, 2001; U.P.1, 2019). Enkindle, PISEP, SHS and USC's rooftop solar project and the one-time RE donation drive aimed to provide energy-poor and disaster-vulnerable areas with sustainable RE solutions to address their lack of, or limited, energy access. Furthermore, by establishing or enhancing various forms of the communities' social capital, the project implementers encouraged the beneficiaries to take a more active role in the projects' initiation and deployment. At the same time, the communities benefited from the projects' RET solutions, which were designed to address the communities' immediate energy needs. For instance, the project teams applied various community-based mechanisms (stewardship, management, and ownership schemes) to ensure that the beneficiaries had a role to play in the RE project. As a result, the community members were involved as recipients of the RETs and as stewards, managers, and owners of the systems. At the very least, all of the project teams informed the beneficiaries about how to use, operate and take care of the RETs. At the household level, regular checking and cleaning of the solar panels and monitoring of the inverters became a part of everyday life. This was especially true when the physical components of the RETs were still working. The relationship built between the project implementers and the beneficiaries also brought direct benefits to the communities. For example, lighting and mobile charging were essential for improving the quality of life in remote villages. The beneficiaries also became aware of the other benefits of RETs, like reduced noise and waste pollution, and the fact that they provide a cheaper alternative to diesel fuel.

If the projects are evaluated against their objectives of 1) providing energy access to the communities and the benefits that RETs brought to the communities and 2) inducing greater participation of the beneficiaries in the RET adoption process at the initial stage of the project, all of them can be considered to have been successful. The communities benefited from the electricity the RETs provided and were able to utilise the RE to aid them in their day-to-day activities. Agent-centric theories on RET adoption support this evaluation. Agent-centric theories define successful adoption as a change in a person's behaviour due to the utility the technology brings, despite the uncertainty (Rogers, 1983). It also occurs when new and unfamiliar technology is incorporated into daily routines and everyday life or domesticated (Haddon, 2011; Silverstone, 1994).

Furthermore, all of the community-based RE projects (apart from the one-time donation RE drive) aimed to have systemic change to achieve RET adoption in the communities– not only in the usage of the physical components of the RETs but also in terms of the social institutions and networks within the community. Enkindle, PISEP, and even the smaller solar-scale projects like the SHS and USC solar rooftop projects invested in creating and enhancing local mechanisms, relationships or organisations in order to maintain and manage the RETs. The stakeholders involved were not only the users of the RETs and the project implementers but also other community members, representatives of formal and informal institutions, like barangay officials, NGOs, community associations, religious affiliations and people with family ties. There were formal structures in place, like community deliberations and voting, to engage the island residents in decision-making processes about the solar farm. In short, the community-based RE projects recognised the roles of the social and immaterial components of the community in the success or failure of RET adoption.

Discussion

The question remains whether each project resulted in sustainable RET adoption in the community. As emphasised in the analytical framework, the paper defines long-term RET adoption as a situation in which the different components (hardware, software and orgware) co-produce and co-evolve with each other over time. It is a process that circulates among the various actors and stakeholders across time and geographic scales (Sovacool & Hess, 2017, p. 733). This paper finds that each of the projects discussed in this study faced challenges in sustaining and maintaining its community-based approach to ensuring an extensive diffusion of RETs in the community. The problems became more prominent when the physical components (hardware) of the RETs started to deteriorate, and the capability of the community to repair and replace the spoiled parts (software) was insufficient. Most importantly, the projects' community-based RE mechanisms and structures (orgware) were not sustained beyond the RETs' lifespan.

The intended outputs of each project were achieved, and these had beneficial impacts on the communities. However, the assessment regarding whether the projects were successful **varies** for each community-based RET project, depending on whether the different components of the RET adoption process were still in place and whether they co-evolved to address the current energy needs of the communities during the period of study. Specifically, this refers to 1) whether beneficiaries are still using the physical components of the RETs (hardware) to provide at least their basic energy needs, 2) whether they can continuously operate and manage the RETs (utilisation of software), and 3) whether the community and project mechanisms for sustaining the RETs are still present (orgware). *In this case, except for the eight Enkindle RETs in Alang-alang and the two ongoing projects (SHS in Pangan-an and the USC rooftop in Gilutongan), most of the community-based RE projects failed to continuously produce, evolve, and maintain the different building blocks of long-term RET adoption process*. The following paragraphs explore this in depth.

Most of the one-time donated RETs in Gilutongan were left to the care of individual households or beneficiaries (in the case of the school). Once they started to malfunction, they were left unused, especially in the case of low-income families that lacked discretionary funds to buy spare parts. Similarly, 12 Enkindle RETs were unmonitored or new components needed for them to function continuously were not provided. The basic knowledge and skills of the communities were only sufficient to allow them to operate the RETs while they were still in a good condition. Likewise, PISEP in Panga-an had a promising start with their centralised solar farm managed by PICCD. The island was solely dependent on solar energy for 13 years until the batteries, solar panels, and other hardware components started to fail. The orgware of each project faced constraints that affected sustainability.

RE stakeholders (both the project implementers and the communities) failed to follow the "rules of the games continuously" in terms of their role in managing and sustaining the RE projects. For example, Enkindle faced difficulties in retaining manpower, funding new deployments, and regularly monitoring the RETs. They also experienced internal management challenges that led to the restructuring of the

Table 3
Overview of community energy projects (description, beneficiaries, deployment, and status).

Project name	Project description and implementers	Island communities/ beneficiaries	Type of RET system	Years of operation of the RET system	Beneficiaries or end users	Institutions involved in the project	Current status of the community-based RE project
Project Enkindle	An RE deployment project aimed at empowering the rural communities affected by Typhoon Haiyan Initiated by a group of individuals in Singapore; currently managed by an NGO and a university	Bantayan, Camotes, Malapascua and Alang-alang	Class 1: community-based solar PV systems ranging from 50 W to 800 W capacity and Class 2: 300 W hybrid RET with solar and wind energy	2014–2020 for eight Class 1 RETs; for the rest, they lasted at least two years	Individual households and communal facilities	NGOs, barangay officials, local university, religious organisations	Management was taken over by an NGO and a local university
PISEP	The first off-grid RE rural electrification project in the Philippines, aimed at providing 24-h electricity to Pangan-an Island Initiated by the national government	Pangan-an	Centralised solar PV system comprising 504 PV modules, with a combination of 80 and 90 W peak each, totalling 45.36 kWp, with a 20-year lifespan	1998–2011 was solar farm alone; 2012–2017 was solar farm with a diesel generator	Individual households and communal facilities	National government, Department of Energy and the barangay officials	PICCD manages the diesel generator; DOE took over the management of the solar farm
SHS	Part of the national government's Total Electrification Programme to power up off-grid rural and remote areas Initiated by the national government		10 Wp to 30 Wp – enough to power light bulbs and a small radio, and to charge mobile devices	2018–2020	Individual households		Ongoing
Donated RETs (general)	A one-time donation drive by external organisations and donors	Gilutongan	SunEdison 5 kW solar PV system donated to Gilutongan Elementary School and other one-time donations of smaller scale solar PV	2015–2018 for the school; at least two years for individual household solar PVs	Individual households and community centres, like the school	External donor organisations, barangay officials	n/a
Rooftop Solar PV Project	An ongoing community-based RE project organised by USC in Gilutongan aimed at establishing and sustaining rural electrification in the island using RETs USC as part of Access to Sustainable Energy Programme-Clean Energy Living Laboratories (ACEP-CELLs), funded by the European Union		A 7.92 kWp rooftop solar PV system with 24 units of 330 W solar PV panels, two units of 5 kW inverter, and 12 units of 200 Ah battery	Started in March 2020 and lasted until 2022	Selected household beneficiaries who have the lowest voltage received from the diesel genset	USC, barangay officials	Ongoing
Self-bought RETs	n/a		Mini solar panel with 10 to 50 W to power appliances like a bulb, a mobile charger or a radio	At least three years	Individual households or household with businesses	None	n/a

Table 4
Different community-based mechanisms used by the project implementers and the various avenues by which communities participated in the project.

Project name	Different community-based mechanisms used by the project implementers and the various avenues of community participation				
	Pre-deployment activities	Knowledge transfer	Establishment or enhancement of local institutions to sustain the system		Formal and informal institutions and networks involved within the community
Project Enkindle (Bantayan, Camotes Malapascua and Alang-alang)	Feasibility studies, socioeconomic assessment and community survey	Basic installation, repair and maintenance	Stewardship	Signed agreement among stakeholders to maintain and monitor the RETs, with different roles for each	Existing community organisation (NGOs, barangay officials); personal contacts, familial ties, religious affinity and beneficiaries
PISEP		Basic installation, repair and maintenance; business and *management skills training, to sustain the RETs*	Community management	Creation of a community cooperative to manage and sustain the RET: PICCD	State institution (DOE); existing community organisation (barangay officials); creation of community-based organisation by the beneficiaries
SHS: Gilutongan		Basic installation, repair and maintenance	Ownership and community management	Creation of smaller community organisations to manage the SHS	
Rooftop Solar PV Project: Gilutongan		Basic installation, repair and maintenance; *load management to sustain the RETs*	A phased approach to ownership and management	Control and ownership depends on the community's deliberations, which are facilitated by the project implementers	Existing community organisation (barangay officials); creation of community-based mechanisms by the beneficiaries
Donated RETs (general)	Unknown	Basic installation, repair and maintenance	Ownership and individual management	None	Existing community organisation (barangay officials)

organisation. These project management problems adversely affected the stewardship programme and, most importantly, the transition of the communities from using the Class 1 system to using Class 3.[3] An exception was the RETs deployed in Alang-alang: eight of these are still working and are regularly monitored by the stewards, despite the changes in the Enkindle management team.

Similarly, PICCD's management capabilities were tested – including their ability to convince end users to pay, or to come up with supportive mechanisms to provide financial support to low-income families so they could afford to pay their electricity bills. They could not raise enough funding *on their own* to continuously operate, repair and maintain the solar farm. Their livelihood projects were temporary and were unable to support the community's low-income families. Community deliberations were challenged due to transparency issues, and the collection of electricity fees from the residents was more difficult than expected.

The DOE's SHS programme in Pangan-an and the USC's rooftop solar PV projects in Gilutongan were launched in August 2019 and March 2020, respectively. The data gathered during the fieldwork indicated that all of the RET hardware components were still working, and the community mechanisms for driving the RE project were still in place. There was a feeling of direct control over the energy consumption at the household level since the SHS and rooftop solar PV had been installed inside people's houses, and the beneficiaries could easily monitor their usage. At the community level, the orgware of both the SHS programme and the USC solar rooftop projects were also in place to regularly monitor and manage the RETs. The SHS users in Pangan-an elected an RE management team for each village. In contrast, the USC team used the phased approach[4] to build the technical and management capacity of the 11 selected beneficiaries. As a result, they were able to directly monitor their electricity consumption. Furthermore, the collection of monthly fees was more manageable since the households were located near each other.

Regarding the SHS programme, the beneficiaries felt that the distributed RETs and decentralised organisational structures were more effective in terms of user control and the management of RETs. For instance, the interviewees from Pangan-an claimed that smaller decentralised organisations were better than a centralised management team because they felt closer to the people in power and the decision-making process was more transparent (Pangan-an, H3, 2019; Pangan-an, H4, 2019). When asked during the interviews, the beneficiaries claimed that they could easily approach the SHS management team because there was mutual trust between them. Whenever they experienced any technical difficulties or needed to carry out repairs on their RETs, they could simply ask for help from the head of the SHS team (who had been their neighbour for a long time). The proximity of the beneficiaries to the management team was also helpful in easing the process of monitoring the payment of electricity dues.

Similarly, informal institutions also played a crucial role in the sustainability of the community-based approach of the RE projects. Enkindle Alang-alang have active RET stewards, with strong communal ties with the beneficiaries. The mutual trust and close personal relationships made managing the RETs easier. There was a feeling of assurance that each RE stakeholder was doing their job to take care of the system because of the presence of *hiya* (a sense of shame) and *utang na loob* (a debt of gratitude) (Leyte H. 10, 2019; Leyte H. 8, 2019). These households were either related by blood, friendship or religious affiliation, and they lived close to each other.

Likewise, the phased approach applied by the USC team proved to be efficient, not only in establishing trust between the project team and the beneficiaries but also in regard to understanding the more salient societal characteristics of the island. The interviews with the project team revealed that the central part of the project was not the deployment of the physical components of the RETs alone but rather the preparation work before the actual deployment (U.P. 3, 2019; Gilutongan, H6., 2013). The USC project implementers invested more time in the initiation phase of their rooftop solar PV project in Gilutongan, before deploying the RETs on the island (U.P. 2, 2019). This was crucial in building the community's capabilities to adopt the RETs and to *adapt* to the possible changes that the deployment might bring to the island. The

[3] During the fieldwork period, no Class 3 systems were deployed in the communities.

[4] In technology-based and development projects, a phased approach usually divides the process into multiple phases. This begins with the initial stages or the initiation phase, which focus more on gathering first-hand information about the beneficiaries, their characteristics, and cultural nuances (PM Alliance, 2010). This is followed by the planning phase, where the technology and project management systems can be designed for roll-out; and the execution, which involves deployment, tracking, monitoring, facilitating and managing the technologies. Finally, the closing phase includes documentation, evaluation and reassignment of tasks and responsibilities (PM Alliance, 2010; Thamhain, 2014).

community interactions, between the USC project implementers and the island residents, revealed that a holistic technological solution was key to increasing the uptake of RE on the island. The USC project team designed an RET system that addressed the lack of electricity on the island. This system suited the existing political and environmental conditions and the economic needs of the community. Although it would have been technically more straightforward to install an SHS type of solar PV than to install a rooftop solar PV, the latter was chosen to reduce the amount of land required for the project. Most of the residents in Gilutongan do not own their land, and, as such, land use can be a challenge.

The project team also found that any technological solutions on the island should consider the following: aside from the lack of energy access on the island, Gilutongan also lacks potable and drinking water, waste and plastic management, and alternative sources of livelihoods. It was considered that the electricity produced from the RE could potentially power refrigerators or ice-making machines, which could help preserve fish and could offer a source of additional income for households, through their selling iced water and ice.[5] Another possible RE design could integrate a water filtering device. The residents procure water in five-gallon jerry cans, which cost around USD 0.30 per container (excluding labour), from mainland Cordova (Lozano, 2019, p. 908). It was considered that RETs that can power water filters could save residents the cost of electricity and drinking water.

Despite the potential challenges laid out in the previous section, the community-based mechanisms applied by the USC in the solar rooftop project and by DOE in the Pangan-an SHS project are expected to address the communities' lack of energy access through long-term RET adoption.

Conclusions

The findings of this study have profound implications for how community-based RE projects are planned, designed and implemented. First, the conceptualisation of successful technological diffusion that is presented in this study challenges current and future RE projects to (re) evaluate their definition of successful RET adoption. Beyond the deployment of the physical components of the RETs, successful adoption requires a long and continuous relationship with, and engagement with, the community.

Second, distributed energy systems are more viable in off-grid and remote communities, especially where residents live on a day-to-day basis. A crucial aspect is that the distributed energy system must have a decentralised management or organisational structure that will manage, support and sustain the physical components. One of the advantages mentioned by the recipients of the SHS programme was that they could easily approach the SHS management team whenever they had technical difficulties with their RETs. In addition, the collection of electricity payments and monitoring were observed to be easier in smaller groups, as compared to cases with an extensive centralised management system, like PISEP and PICCD.

Third, the capacity development of community-based projects should not be limited to technical know-how regarding operating and maintaining the RETs: it should also involve load management and the improvement of energy consumption to induce savings or other practical concerns that will maximise RE use. For larger-scale RE projects, like the solar farm, capacity building should also be accessible to the RE management team and the rest of the community. The skills needed to manage these RETs include energy planning, forecasting and modelling of demand and consumption, and business modelling for potential livelihood projects.

The multifaceted nature of the structural and individual constraints in communities requires community-based RE projects to acknowledge that there are limitations to CDD as a development approach. For example, it cannot address all community problems, nor can it determine how far communities can participate in the RET adoption process. Such a situation poses two critical challenges to RE project implementers and policymakers: (1) to have continuous, inclusive and supportive mechanisms by which communities participate in the RET adoption process (this moves beyond "one-time big-time RE donation drives"); and (2) to provide a holistic technological and socioeconomic solution to the community: that is, every community intervention to end electricity poverty should emphasise that electricity access is not the end goal, but only a means for individuals to have a better quality of life and to achieve environmentally sustainable development.

The study advocates for more research on community-based projects utilising a relational approach to solidify and substantiate the defined criteria for 'successful' RE adoption. Additionally, it is crucial to periodically evaluate whether these identified successful cases continue to evolve and meet community needs over time.-.

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CRediT authorship contribution statement

Conceptualisation, A.T., M.Q; methodology, A.T. and M.Q.; validation, A.T.; formal analysis, M.Q. and A.T.; investigation, M.Q. and A.T.; resources, A.T.; data curation, M.Q.; writing and editing M.Q. and A.T.; supervision, A.T.; funding acquisition, A.T. All authors read and agreed on the published version of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appear to influence the work reported in this paper.

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[5] "Ice yelo", literally translated as "iced ice", is a colloquial term for a solid block of ice that is usually made by filling a soft drink bag (a 4″ × 10.5″ or 4″ × 12″ plastic bag) with water and freezing it. Ice yelo is a commodity sold in *sari-sari* stores. For islands like Gilutongan, this is a luxury good because not everyone has refrigerators or freezers.

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