Challenges for implementing renewable energy in a cooperative-driven off-grid system in the Philippines

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Abstract Implementing renewable energy on Philippine islands is essential for sustainable development. Electric cooperatives play a key role to provide renewable energy to marginalized and remote communities not profiting from private sector interest. However, a low-carbon transformation of energy systems implies political, economic, technical, and societal risks and uncertainties. Here, we investigate those faced by the Romblon Electric Cooperative (ROMELCO) in installing one of the Philippines' first off-grid, hybrid energy system in the small and remote island of Cobrador. We apply a transdisciplinary mixed methods approach including expert interviews, surveys, and focus group discussions. We identify the most serious implementation risk faced by ROMELCO as the discontinuity between the policy pronouncement and implementation practice. We contribute with an analysis of ROMELCO's actions to address the complex bundle of implementation policies and programs for a wider replication and scaling up of cooperative based power supply.

Keywords Philippines, Cooperative, Community energy, Energy access, Decentral energy, Risks

1 Introduction

Pursuing a low-carbon energy transition pathway is essential for the Philippines since the country is one of the most vulnerable to climate change (Viña et al., 2018). Disasters like the Super Typhoon Haiyan (2013) underlined the threat of extreme weather events on the country's infrastructure and are projected to occur more frequently with increasing temperatures (Holden and Marshall, 2018). Additionally recent research highlighted that effects of climate change threaten societal peace and may increase the intensity of conflicts in the country (Crost et al., 2018). The Philippine government finally ratified the Paris agreement in 2017 and committed itself to cut emission by 70% compared to the business-as-usual (BAU) scenario (Crost et al., 2018). But as one of the fastest evolving countries in Southeast Asia (Mondal et al., 2018; Viña et al., 2018), the Philippines is also compelled to meet an increasing energy demand for economic development. As it is, more than 11 % of the population have no access to electricity and a much higher share of the population suffers from unreliable power supply (IRENA, 2017). Given these conditions, it becomes evident that it is in the country's inherent interest to increase power generation capacities in an environmentally sustainable manner.

As early as 2008, the Philippines implemented one of the most ambitious renewable energy (RE) acts of the region, which includes several mechanisms and schemes to support private sector initiated RE deployment (Mouton, 2015). The intention was to encourage private sector investment in RE deployment in the country's remote islands and thus contribute to improving energy security and energy access in those remote islands. However, 10 years after the implementation of the RE act, private sector involvement in providing electricity access through RE is still low (DoE, 2016a). Therefore, alternative institutions are considered to advance energy access and RE deployment. Rural electric cooperatives (EC) were encouraged to fill in the gap in energy generation. EC are customer owned corporations whose original mandate initially focused on power distribution in its service areas.

Yadoo and Cruickshank (2010) highlighted that EC can advance rural electrification when private sector involvement fails. Advantages are lower revenue expectations and higher interest in local development (Yadoo and Cruickshank, 2010). Additionally, experiences from community owned and locally initiated low-carbon energy supply projects highlighted societal, economic and environmental benefits (Brummer, 2018). With growing societal interest in clean energy supply in the Philippines, EC could enable integrating local initiatives and interests leading to RE development. However, EC face risks and uncertainties when stepping into RE development and expanding their services to not electrified islands.

This study looks into the risks and uncertainties confronted by one exemplary electric cooperative in the Philippines as they clear a pathway towards low-carbon transition in their franchise area. Uncertainty is conceptualized as a state of perception, which may be lacking, incomplete, or contested due to variability or lack of knowledge (Asselt, 2013). We further distinguish uncertainty as epistemic uncertainty (lack of knowledge), paradigmatic uncertainty (what is known), or translational uncertainty (disagreements on what is known). Risk is defined as the probability of loss, failure, or negative outcome on different dimensions (Haimes, 2009). Risks can be classified as implementation risk (barrier) or as consequential risk (outcome). In this study, we identify risks and uncertainties through a mixed methods approach that combines quantitative and qualitative research, the nature of the uncertainties faced by the Romblon Electric Cooperative (ROMELCO) and the types of risks they encounter as a consequence of installing one of the Philippines' first off-grid, hybrid energy system in the small and remote island of Cobrador. The perspectives of different stakeholders are taken into account: Through a household survey, expert interviews, and focus group discussions, the diverse vantage points of energy sector experts, EC officers and members, island community leaders, and household heads and members were gathered to gain a holistic assessment of risks and uncertainties. The result is the transdisciplinary understanding of a specific pathway to a low-carbon energy system.

2 Background: Low carbon energy development in the Philippines

This chapter serves for the contextualisation of the presented case study on challenges for cooperative-driven off-grid system in the Philippines. Therefore, we present relevant findings from academic literature (2.1), provide an overview about the remote island landscape of the Philippines (2.2), outline the policy framework for low carbon development (2.3) and introduce the specific case study (2.4).

2.1 Renewable energy and island electrification

This case study of a cooperative-driven RE off-grid system in the Philippines builds upon previous findings on RE-based island and off-grid electrification, which find that RE is a suitable technology for powering islands due to their isolation, remoteness, and lack of conventional energy sources (IRENA, 2014; Kuang et al., 2016). Given the prohibitive costs for submarine power cable interconnection (Kuang et al., 2016; Schell et al., 2017), island energy systems are most commonly isolated systems, also referred to as off-grid or decentralized energy systems. Such energy systems are considered hybrid, if more than one power generation technology is applied (e.g. solar-battery-diesel hybrid system); an overview on hybrid system configurations is provided by (Bajpai and Dash, 2012). Specific characteristics of insular energy systems and challenges for RE integration are described by (Erdinc et al., 2015). Neves et al. (2014) analyse 28 hybrid energy systems on islands: The majority is located in Europe and serves a small population (< 10,000), mainly with a mix of wind power and diesel generators.

Studies that quantify the market potential for RE hybrid systems based on case studies (Gioutsos et al., 2018) or based on global scale analysis (Blechinger et al., 2016; Meschede et al., 2016) find a significant market potential for RE in the Asia-Pacific region. Weir (2018) underlines the relevance of RE deployment for the pacific island states (PIS), with regard to vulnerability to climate change, dispersed geographies and dependence on fossil fuels. The same motivation holds true for the Philippines with very similar natural conditions (Brahim, 2014). Nevertheless, main barriers for wider deployment are the complexity and maintenance efforts of hybrid energy systems, combined with financial and institutional shortcomings in PIS (Weir, 2018). Hazelton et al. (2014) reviewed experiences with PV-hybrid energy systems and found that energy demand uncertainty and inappropriate business models are the most decisive barriers to wider deployment. Yaqoot et al. (2016) summarized technical, economic, institutional, socio-cultural and environmental barriers to the dissemination of decentralized RE systems described in the academic literature. They found that for RE mini-grids, technological appropriateness and skill requirement (technical), high cost and lack of access to credit (economic), and an inappropriate regulatory framework (institutional) are the most decisive barriers. Other case studies highlight challenges for the wider deployment of off-grid technologies in remote regions and for island electrification, such as customer reliability and low project profitability (Lahimer, 2013), remoteness and low population densities (Mandelli, 2016) and unpredictable energy demands (Boait et al., 2015; Riva et al., 2019). Moreover, rural communities are inadequately integrated prior to project implementation which leads to a lack of social acceptance and inappropriateness of services (Sovacool, 2012; Hirmer and Cruickshank, 2014). Lack of education, proper technical training and awareness, which often leads to failure in proper installation, operation and maintenance of RE systems are also significant barriers to wider deployment in developing countries (Yadoo and Cruickshank, 2012).

For the Philippines the deployment of RE for remote area electrification is promoted since the early 90s (Heruela, 1992). A significant potential for RE on remote islands specifically for the Philippines has been identified by (Barley et al., 1999) and more recently by (Bertheau and Blechinger, 2018). Foley and Logarta (2007) identify that widely scattered islands, poorly developed infrastructure and communication systems hinder universal electrification. Additionally, they find that insufficient institutional capacities decelerate remote island electrification. Marquardt (2017) comes to a similar conclusion by identifying unclear political responsibilities, conflicting regulations and weak local capacity as major obstacles for the electrification of remote islands through RE in the Philippines. Rationalization of planning and implementation procedures for RE projects is needed to take into account the specific characteristics of small-scale RE projects for smaller islands (Roxas and Santiago, 2016). A sustainability assessment of a RE-based hybrid energy system for the case study of Pangan-an island found that the eventual failure of the project and deterioration of the energy systems was a result of non-affordable electricity rates and the low quality of the applied technology (Hong and Abe, 2012). Weak managerial capacity and insufficient maintenance then led to the ultimate malfunction of the energy system (Hong and Abe, 2012; Hong et al., 2015).

2.2 Remote island landscape & energy access in the Philippines

In terms of power supply, the Philippines distinguish between “on-grid” and “off-grid” areas. The main islands in Luzon, Visayas and Mindanao are considered as “on grid” areas whereas the remaining islands are “off-grid” areas (Boquet, 2017). The on-grid areas profit from relatively stable power supply provided through two main electric grids (IRENA, 2017). RE generation make up a share of 25% (mainly geothermal and hydropower) in the on-grid areas, however, in order to cover the increasing demand, a massive expansion of coal-fired power generation is projected. The electricity costs are among the highest in entire Southeast Asia, and almost as expensive as Singapore’s (DoE, 2016b).

Most of the off-grid areas suffer from insufficient or even no power supply at all. More than 280 small island grids are operated (DoE, 2016a), mainly applying diesel generators for power supply (Roxas and Santiago, 2016). This does not meet the economic and environmental targets of the country for several reasons: (1) The lack of substantial domestic oil sources lead to a dependency on global oil markets (Roxas and Santiago, 2016). (2) High generation costs make the subsidization through the universal charge for missionary electrification (UCME) scheme necessary. (3) Combusting diesel fuel comes with emissions and the risk of oil spills (Viña et al., 2018). (4) Only in 36% of the small islands, is electricity available for 24 hours (DoE, 2016a). However, for these islands, a high potential for RE was identified (Bertheau and Blechinger, 2018). Pursuing a low-carbon development in “off-grid” areas is important. Low-carbon energy systems can increase energy access (Surroop et al., 2018) and energy security (Wolf et al., 2016). Additionally, successful low-carbon energy projects can serve as a blueprint for further RE deployment.

The government of the Philippines (GoP) acknowledges the importance of developing clean energy technologies in smaller grids not only for the reduction of emission but also for the improvement of living conditions as stated in the definition of Sustainable Development Goal (SDG) #7 (Gupta and Vegelin, 2016). 100% electrification of all households by 2022 was set as target within the Philippine Energy Plan (PEP) (DoE, 2016c). Despite many ongoing projects and initiatives to improve electricity access, the share of electrified households was only at 89.6% in 2016, reflecting 2.36 million households without electricity supply (IRENA, 2017).

2.3 Policy framework for low carbon energy development in the Philippines

After the experience of a nationwide shortage of electricity supply lasting for an entire decade (1990s) the restructuring of the power sector was initiated (Mouton, 2015). The once entirely state-owned electricity sector was reformed and largely privatized in 2001 with the enactment of the Electric Power Industry Reform Act (EPIRA) (RA9136, 2001). The adoption of the Renewable Energy Act (RE Act) in 2008 (RA9513, 2008), was intended to accelerate the deployment of RE technologies in the country (Roxas and Santiago, 2016). High expectations were put on the RE Act given the number of fiscal and non-fiscal incentives to be implemented under it (Rosellon, 2017). Both the EPIRA and RE act are policies aiming at stimulating private sector involvement in supplying the off-grid areas besides the “on-grid” sector. Therefore, two basic schemes for private sector investment were designed: The qualified third party (QTP) scheme and the new power producer (NPP) scheme. The QTP scheme allows for power generation and distribution in an “off-grid” area, whereas the NPP scheme enables the private sector to take over power generation from NPC-SPUG (National Power Corporation – Small Power Utilities Group), the residual unit of the former state-owned monopolist. Figure 1 visualizes all options for supplying off-grid areas and the entities involved. The remaining not yet privatized public power generation and private power generation (NPP & QTP) is regulated and supervised by the Department of Energy (DoE), the Energy Regulatory Commission (ERC) and the National Electrification Administration (NEA). Power distribution is handled by the EC or QTP, purchasing power from one of the before introduced entities. Recently, the EC have been encouraged to expand their activities into power generation by Rep. Act. No 10531 (RA10531, 2012). For a large but not quantifiable number of very small islands power supply is informally organized.

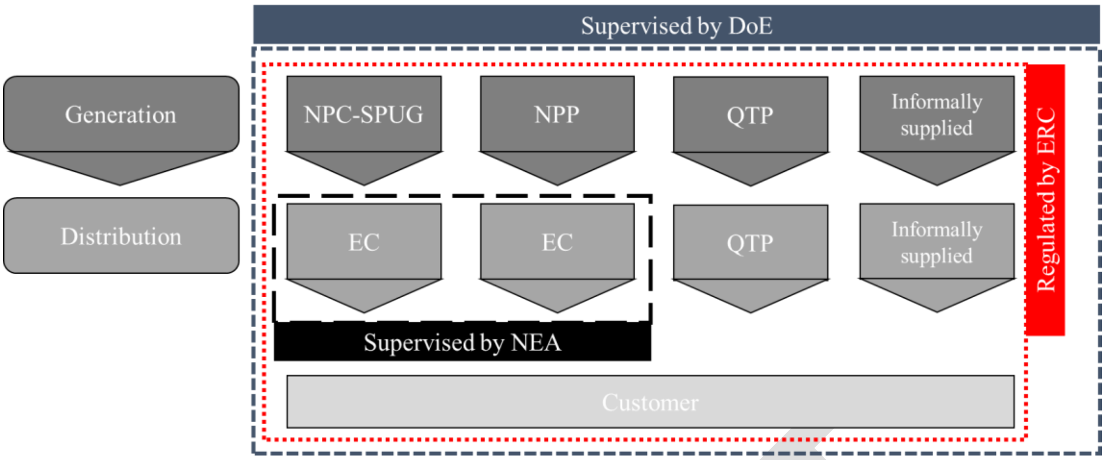

Figure 1. Draft visualizing the options for supplying off-grid areas highlighting entities in generation, distribution and regulation (own visualization).

The QTP and NPP scheme should facilitate rural electrification through private sector participation. However, the impact is disappointing. As of now, two QTP projects were realized (DoE, 2016a) and NPP investment focuses on few economically attractive areas. Main reasons are the very complex application procedure, which imply high risks and uncertainties for project developers. Additionally, the remote areas do not pose a very attractive market for private sector investment, calling for another type of institution to step in. Given the lack of interest of the private sector and the incapability of the public sector in implementing low-carbon energy systems in remote islands of the Philippines, the question arises which other institution could take over this task. With this study, we consider the EC as eligible for fulfilling the role of advancing energy access and at the same time deploying low-carbon energy systems in the country. Nevertheless, if EC can fulfil this role is diversely discussed: EC are accused of underperformance and considered as blocking universal electrification (Lectura, 2018a). In fact, the management of some EC is subject to corruption, local political influence, and non-performance. However, such an accusation cannot be generalized to all EC, since the majority of EC received positive ratings by NEA, which oversees the EC (Lectura, 2018b). High potential arises from the EC lower profit interests, higher interest in local development, more detailed understanding of community's needs, and ownership structure.

2.4 Case study: Electric cooperatives as driver for low carbon energy development

This study focuses on the Romblon Electric cooperative, one of the most active EC in deploying RE in the Philippines. ROMELCO is situated in Romblon island and supplies a population of more than 23,000. The case study is focused on ROMELCO's latest low-carbon energy development project on Cobrador island. It has a total land area of 2.6 km² and a population of around 1,000 people or 239 households. Before 2016, electricity was provided to the community by a diesel generator (15 kW peak capacity) for a total of eight hours per day. In 2016, ROMELCO together with the Asian Development Bank (ADB), the Korea Energy Agency (KEA) and NEA has implemented a joint project on Cobrador Island, leading to the installation of a solar-battery-diesel hybrid system in August of the same year. The hybrid system consists of a solar capacity of 30 kW, battery (lithium-ion) capacity of 200 kWh and a diesel back-up generator of 15 kW. The hybridization improved the reliability of supply (24 h), affordability (50% tariff reduction) and environmental soundness (RE share up to 90% per day).

3 Material and methods

A mixed-methods approach that combined focus group discussions, expert interviews, and a household survey was used to analyze the uncertainties and risks as defined by (Asselt, 2013), faced by EC when pursuing low-carbon energy development in the Philippines. The results of the expert interviews that serve for a macro-level analysis, of the focus group discussions (FGD) with local leaders that provide micro-level perspectives, and of the survey that give empirical evidence on the household-level were triangulated to get a richer account of the uncertainties and risks of low-energy transition in remote islands in the Philippines. The different activities of our approach were conducted in February and March 2018, starting with expert interviews in Manila. During the subsequent field stay, the FGD were held first as they also served for informing the local government unit about the overall goal of the study. The household survey was then conducted within three weeks in late February/early March.

3.1 Expert interviews

Expert interviews were conducted to map out the institutions and actors involved in low-carbon energy development and to identify risks and uncertainties for such development. A total of ten semi-structured interviews were conducted over a three-week period in February 2018. Key criteria for the selection of experts was to represent stakeholders from the government sector, business sector, civil society, development cooperation, and academia. The individual experts were approached based on the extent of their involvement in off-grid electrification through EC in the Philippines. Each of the experts hold positions related to clean energy development partly with special focus on the off-grid sector in the Philippines. An overview on involved experts is provided with Table 1. They are also involved in policy development/analysis, RE research and RE implementation. Additionally, the selected experts have been involved in the case study project directly through implementing the project (e.g. representatives of electric cooperative or government institutions) or indirectly through providing advice to involved stakeholders (e.g. academia). Therefore, extending the group of experts to a wider field was not considered in order to maintain a comparable level of expertise.

Table 1: Overview on experts considered for interviews.

Expert background	Description	Number (10)
Government institution (GI)	Senior staff of Department of Energy & National Electrification Administration	3
Electric cooperative (EC)	Senior management staff	1
Civil society (CS)	Senior staff of NGO	1
Development cooperation (DC)	Senior staff of foreign development agency	2
Academia (AA)	Research staff involved in technology, policy and economic research	3

Most interviews were conducted face-to-face, only one interview was conducted via teleconference. The interviews were held in English and each interview lasted 30-60 minutes using open-ended questions. Respondents were guaranteed confidentiality and anonymity to encourage unbiased responses and respect institutional review board procedures concerning research on human subjects (Jong et al., 2016).

Table 2 provides an overview of the lead questions for the expert interviews, which were developed based on a review of related literature (Lamnek, 2010). The interviews were recorded and subsequently transcribed into a written summary, focusing on the essential contents for the research interest (Flick, 2007; Reuber et al., 2013). For the analysis, the interviews were thematically coded, following the stepwise approach of Flick (2007): First, specific statements directly related to the central questions are summarized. In a second step, categories according to the research questions are built for each interview, followed by thoroughly, comparing all different interviews using those categories and thereby identifying overlaps and differences.

Table 2: Guiding interview questions.

No.	Question
1	What is your current position and how are you involved in electrification through RE in the Philippines?
2	What are key driving forces of electrification in rural areas in the Philippines?
3	What are major risks and uncertainties for electrification planning in rural areas?
4	What do you consider as possible solutions and strategies to mitigate the uncertainties and risks?

3.2 Focus group discussion

FGD were conducted to examine the narratives of shared experiences of those directly involved in the implementation of the island energy project at the ground level. The FGDs were an exploration into the 'lived experience' of people on the ground, who are blazing a pathway to a low-carbon energy system (Creswell and Clark, 2010). The FGDs provide the specific examples based on actual experiences that elaborate on the themes that were eventually, generated from the expert interviews and help explain some of the results of the household survey. They probed beyond the macro-structural level of analysis (i.e. market-oriented, technology-driven, or policy environment assessment of risks and uncertainties) that pervades most energy studies, to render more audible the voices of people on the ground who confront these risks and uncertainties in daily life, and to render more visible the emotional labor that energy projects require. These FGDs are therefore a useful complement to the other methods used in this study.

Participants were considered for the FGD based on their shared experience of the process of implementing a low-carbon energy system in Cobrador Island. For this study, the identified focus groups were the group of ROMELCO officers and the group of local leaders in the island of Cobrador. Two (2) separate FGDs were conducted, with each FGD lasting for approximately an hour. Five (5) officers and members, including the General Manager, attended the FGD with ROMELCO. The FGD in Cobrador island involved ten (10) island residents and representatives of sectoral organizations in the island. The discussions were mainly about their recall of the most important factors, which made possible the low-carbon energy system's emergence, the problems and difficulties that they encountered and how they transcended these, their assessment of the key outcomes of the project in various areas of life in their communities, and their main motivation in maintaining the system. The discussions were audio recorded with permission from the participants and researchers noted down process observations. These recordings and the researchers' observation notes were then transcribed to enable the generation of themes (Stewart et al., 2006).

3.3 Household survey questionnaire

The survey questionnaire consists of 58 main questions, with additional follow-up and sub-questions. The questionnaire is comprised mainly by closed-ended questions but includes some open-ended questions (Sullivan and Barnes, 2006). The focus of the survey was to investigate on the socio-economic impact of low-carbon energy development projects on local beneficiaries, thereby indirectly anticipating risks and uncertainties for EC driven low-carbon energy development. Sections and descriptions on the questions are provided in Table 3.

Table 3: Questionnaire structure.

Section	Description of questions	Rationale
General socio-economic information of the households	Household size, adults/children, age, education status, main income sources and expenditures	Setting basic socio-demographic context and providing key information for interpreting the survey results
Electricity demand and usage	Electricity bill, willingness to pay, appliances (what, how many, since when, how often used), activities with electricity	Enables a detailed understanding of the usage of electricity
Subjective perceptions of changes	Impact of electricity access on health, security, education, safety and income	This data allows for an understanding whether residents perceive an impact of electricity on their daily life
Energy sources	Rating of different energy sources in terms of environmental friendliness, costs, appropriateness for island	This data enables an understanding if residents are aware of different energy sources and if RE play a role in their choice of electricity source
Challenges	State major challenges for the household and the island within the next two years	Enables an understanding of the major concerns of the residents and if they are related to electricity access.

Students from the University of the Philippines Diliman who served as enumerators implemented the survey. The questionnaires were in Filipino (Tagalog) and the assisted completion of each using a tablet lasted for approximately 60 minutes. In order to meet the ethical standards of cross-cultural studies, appropriate local government units, local leaders, and interested inhabitants of the island along with the interviewed households were provided with comprehensive information on the study's content, purpose, and safeguards on keeping the confidentiality of data.

Based on UN recommendations for designing household surveys in developing and transitioning countries (UN-DESA, 2005), the following steps were done as part of a stratified random sampling technique: Data on monthly electricity consumption of all 239 households of the case study island obtained from the responsible electric cooperative ROMELCO, served as stratification variable. At first, natural breaks were used to categorize the entire sample size of households according to the electricity consumption by means of the Jenks natural break method (Jenks, 1967), thereby minimizing the average electricity consumption deviation within each household class and maximizing the deviation of each household class from the electricity consumption average of other classes. In doing so, four different classes were derived of which each should be proportionally represented in the final data sample. The next step was to determine a representative sample size. Taking into account different parameters such as a 95% confidence interval, 5% margin of error and non-response factor (UN-DESA, 2005), a statistically viable sample of 171 out of 239 households was identified. These 171 households were then, randomly selected from all households and the predefined consumption classes by applying a programming code ensuring that each class is proportionally represented. On site, the enumerators identified the randomly sampled households by the help of local government staff or the villagers. For anonymization reasons, households were given codes that were used in the questionnaires.

4 Results and Discussion

The presentation of the results of this study is based on van Asselt's definition of uncertainty and risk (Asselt, 2013). As briefly outlined in the introduction section uncertainty is conceptualized as a state of perception, which may be lacking, incomplete, or contested due to variability or lack of knowledge (Asselt, 2013). Based on Asselt's aggregation of causes of uncertainty we further distinguish uncertainty as epistemic uncertainty (lack of knowledge), paradigmatic uncertainty (what is known), or translational uncertainty (disagreements on what is known) (Asselt, 2013). Whereas risk is defined as the probability of loss, failure, or negative outcome on different dimensions (Haimes, 2009). People identify, give meaning or value, and measure risks from different social position and different periods in time. Risks are therefore context-specific, and can be classified as implementation risk (barrier) or as consequential risk (outcome). Risk and uncertainty are interlinked as risks are arising of the magnitude of uncertainty (Asselt, 2013). For our case study, we understand a "higher" risk with the likelihood of failure of the low-carbon energy system implementation. Uncertainties lead to such risks. Consequently, for each item identified with our mixed method approach we define the type of uncertainty as categorized above and define the resulting type of risk.

4.1 Findings from transdisciplinary research: Risks and uncertainties

Table 4 shows the identified uncertainties and risks from the expert interviews, FGD and household survey. For analyzing our findings, we apply an approach similar to Li & Pye (2018) categorizing the identified uncertainties and risks in the field of Politics (P), Economics (E), Society (S) and Technology (T). We add the category geography (G) and are not considering the category global dimension as it is not appropriate for our research focus (Li and Pye, 2018).

Table 4: Uncertainties and risks identified from transdisciplinary research.

Category	Uncertainty	Risk	Source
Politics (P)	Policy implementation: undifferentiated incentive scheme (epistemic uncertainty)	Implementation risk: failure of the UCME scheme to incentivize the shift to low-carbon energy technologies	Interview with experts FGD with cooperative officers and members
	Policy implementation: undifferentiated fee requirements (epistemic uncertainty)	Consequential risk: high upfront costs even for small and medium-sized cooperatives	Interview with experts FGD with cooperative officers and members
	Energy sector planning and coordination: lack of comprehensive plan and inadequate coordination (epistemic uncertainty)	Consequential risk: stranded assets of cooperatives	Interview with experts
	Bureaucratic procedures: delayed tariff approval and delayed access to subsidy (paradigmatic uncertainty)	Consequential risk: threatened fiscal position or viability of the cooperative	Interview with experts FGD with cooperative officers and members
	Bureaucratic procedures: complex, slow, and rigid (paradigmatic uncertainty)	Implementation risk: failure to attract private sector investment and delayed project implementation for cooperatives	Interview with experts
Economics (E)	Financing and Credit: EC are viewed as lacking in track record and creditworthiness (paradigmatic uncertainty)	Implementation risk: difficult access to finance by small and medium-scale EC, thus disincentivized to engage in RE development	FGD with cooperative officers and members
	Joint venture with private sector: EC are viewed as lacking in capabilities (paradigmatic uncertainty)	Implementation risk: joint venture with cooperatives in RE development remains unattractive for private sector investors	Interview with experts

	Private sector investment into RE: complicated bureaucratic procedures of government (paradigmatic uncertainty)	Implementation risk: investment into RE development remains unattractive for private sector investors	Interview with experts
	Private sector investment into RE in small and remote islands: lack of existing or potential revenue generating economic activities in small and remote islands (epistemic uncertainty)	Implementation risk: investment into RE development in small and remote islands remains unattractive for private sector investors	Interview with experts
	Customer consumption patterns: Inadequacy of energy supply system due to underestimation of increase in customer consumption (epistemic uncertainty)	Implementation risk: Economic viability and system reliability	Interview with experts Survey of household members in island
	Customer income patterns: Unstable and seasonal income of customers (epistemic uncertainty)	Implementation risk: lower revenue stream	Survey of household members in island
	Customer reliability: Lack of commitment and capability of low-income customers to pay electric bill on time (epistemic uncertainty)	Implementation risk: lower revenue stream	Interview with experts
Society (S)	Skilled technicians: lack of locally available technicians in remote islands (epistemic uncertainty)	Implementation risks: - higher cost of operations because of need to incentivize experts to serve in remote islands - delays in necessary repairs	Interview with experts FGD with cooperative officers and members FGD with local leaders in island

	Skilled laborers: lack of locally available workers in remote islands (epistemic uncertainty)	Implementation risk: delayed project implementation	Interview with experts FGD with cooperative officers and members & FGD with local leaders in island
	Resistance: Contending information of the community and the EC regarding the environmental soundness of proposed RE project (translational uncertainty)	Implementation risk: No/delayed project implementation	Interview with experts FGD with cooperative officers and members
	Acceptance of RE: lack of public acceptance of RE due to negative experiences in the past	Implementation risk: No/delayed project implementation	Interview with experts
Technology (T)	Awareness for RE: EC lack of knowledge about RE (epistemic uncertainty)	Implementation risk: Low-carbon energy solutions (off-grid, hybrid) are not explored by many rural EC and local manufacturers	Interview with experts FGD with cooperative officers and members
	Availability of RE technologies: lack of locally available RE technologies (epistemic uncertainty)	Implementation risk: high cost of RE development threaten viability of EC and delays in repair and maintenance	FGD with local leaders in island
	Disaster resilience of RE technologies: lack of RE technologies that are adapted to remote island conditions (epistemic uncertainty)	Implementation risk: low reliability of low carbon energy systems	FGD with local leaders in island
Geography (G)	Accessibility: inaccessibility of remote islands (paradigmatic uncertainty)	Implementation risk: No/delayed project implementation	Interview with experts
	Infrastructure: lack of necessary transportation infrastructure for small and remote islands (epistemic	Implementation risk: No/delayed project implementation	Interview with experts FGD with cooperative

	uncertainty)		officers and members FGD with local leaders in island
	Dispersion of population: difficulty in communicating with customers and in providing service (epistemic uncertainty)	Implementation risk: No/Delayed project implementation	FGD with local leaders in island

4.1.1 Political factors

The UCME subsidy scheme does not distinguish between carbon intensive and low-carbon technologies. Given that low-carbon energy technologies, such as solar PV, are not yet mainstreamed and still costly in the Philippines, using low-carbon technologies in missionary areas poses greater risks for EC. The shift is therefore not necessarily more attractive compared to pursuing the already established and well-known procedures related to the operation of diesel generators.

Fee requirements are the same regardless of the size of an energy supply project. A kW-sized plant has to meet the same bureaucratic and financial requirements as a MW-sized plant. Small and medium-sized enterprises and EC are in effect not encouraged to engage in small or medium-sized low carbon energy development projects, which are in fact the most suitable scale for small and remote islands in the Philippines.

Approval of the tariffs is a requirement for obtaining subsidies from the UCME scheme. In our case study of ROMELCO, tariffs have not been approved even after two years since they filed their application. As of now, the price the EC is charging its customers is not covering its expenses anymore, as it had to adjust the power generation to the increasing demand of its customers. Consequently, when EC develop small-scale projects in small islands, their upfront costs are relatively higher.

The selection procedure for accrediting private sector partners is tedious and slow. In order to get the private sector to participate in missionary areas, the competitive selection process (CSP) was introduced by the government. EC have to go through the CSP in selecting private partners for joint ventures. At least three competing parties are required before a winning bidder may be chosen to negotiate a power supply contract with the EC, which has then to be submitted to the ERC for approval. However, if there is only one party placing a bid, the whole process has to be cancelled and restarted.

Coordination and communication between the involved stakeholders (DoE, NEA, NPC-SPUG, EC) are not sufficient to keep all institutions adequately informed. For example, one expert reported that for the case of one island, the contract for supplying diesel-based power of the public operator was renewed although an NPP was already assigned to replace the public operator. Ultimately, this leads to the risk of stranded assets.

4.1.2 Economic factors

EC could get financing either from financial institutions or from private sector partners. The results of this study reveal that both sectors are reluctant to provide financial support to EC given their low level of trust towards cooperatives. EC are generally perceived as lacking the necessary business track record and creditworthiness.

Officers of ROMELCO identified lack of access to the required capitalization as the crucial factor that hinders small or medium-sized enterprises and cooperatives to venture into power generation in general, and even much less into RE generation. When asked to narrate the story of their own venture into the hybrid energy system in Cobrador island, they preferred to discuss the longer history of their effort: Their experience in their first venture in another island, the Catingas Mini Hydro in Sibuyan island. In that first venture, and based on the stability of their fiscal position as an electric cooperative, they were able to secure a loan from the Development Bank of the Philippines for their initial capitalization in a power generation project. They consider this as a key factor in their eventual ability to venture into another power generation project in Cobrador island as the success of that first venture in Sibuyan island built up their track record and their creditworthiness in the eyes of other key financial institutions in the energy sector.

It is unattractive for private companies to invest in small island electrification as partners of EC, also because of their perception about the existing capabilities of EC. Experts say that most private companies view many of the existing EC as needing to undertake comprehensive organizational and financial restructuring to attain sustainable commercial viability.

Energy projects rely mainly on the returns from the provision of electricity, which means that the potentials for high and increasing revenues remain uncertain. Households use electricity for lighting, and recently for cell phone charging, however electricity usage on a bigger scale and for productive use may not be yet be apparent on most of the small remote islands.

Inadequate energy planning due to underestimation of increase in customer consumption patterns is a major uncertainty for the EC. This comes especially true when a low-carbon energy system is being implemented servicing a community without universal electricity supply yet. For our case study, the electricity demand quickly increased after the implementation of 24 hour service in 2016 (Figure 2).

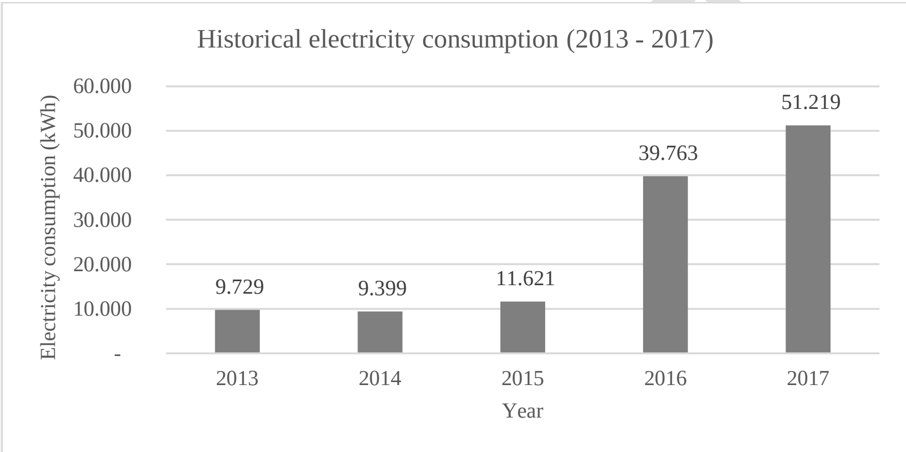

Figure 2. Historical electricity consumption (2013 - 2017).

Although a strong growth of the energy demand was expected, the development exceeded the expectation of experts and planners. One year after implementation the daily energy demand projected for 2021 (180 kWh) was already surpassed. This is underlined by our findings from the household survey. Although a specific inventory of appliances was typical prior to the implementation of the system, there was a surge in the number of appliances purchased after implementation of the system (Figure 3).

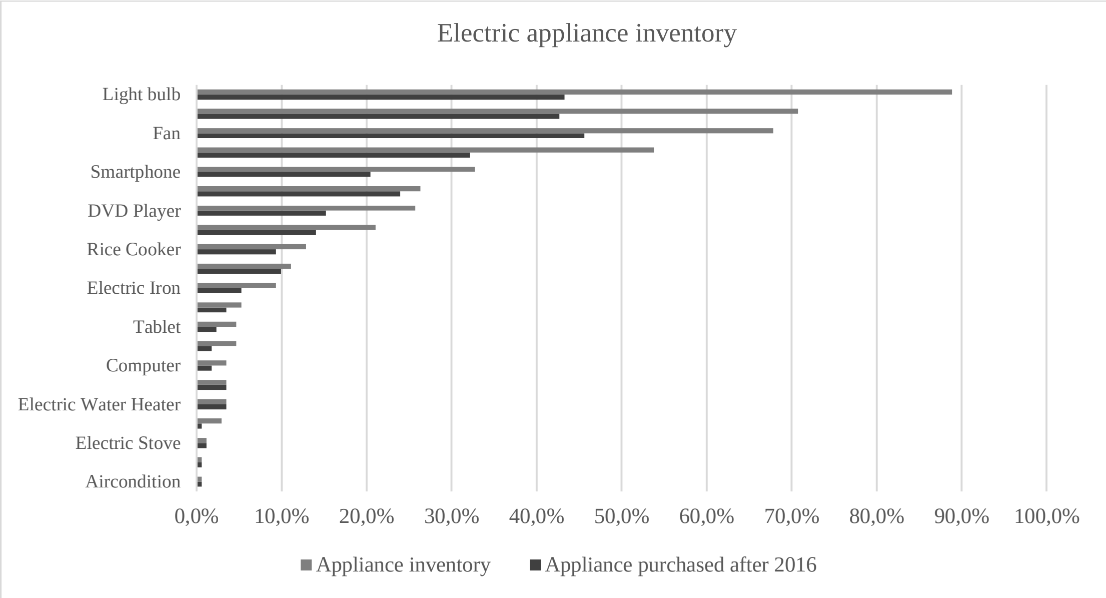

Figure 3. Electronic appliance inventory and share of appliance purchased after implementation of 24 hours electricity supply.

Seasonality in customer income patterns has identified as major uncertainty through the household survey. The greatest share of the households has an income of less than 1,000 PhP (< 20 USD) per week. In order to take into account seasonal variations, the households were additionally asked how much they earn in a "very good" and in a "very bad" week. For a very bad week, almost 40 % of the respondents reported the absence of any income. The main source of income is fishing (61%), followed by remittances of relatives (43%) and farming (34%).

Although our findings clearly highlight the improvement of the safety situation, education, access to information and health supply, the majority of respondents have not experienced an uptake in income since the implementation of the project (Figure 4). The economic situation on the case study island remains similar to the situation prior implementation of the hybrid system.

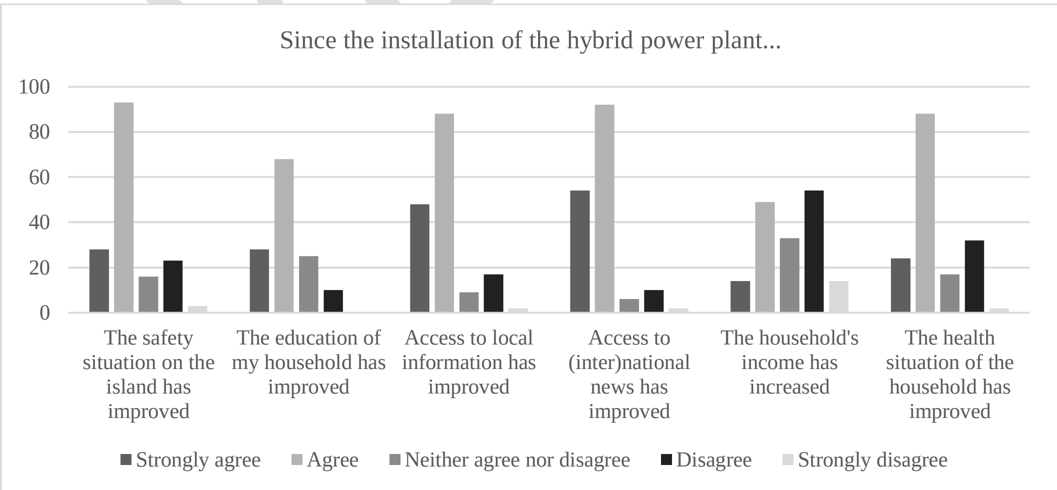

Figure 4. Impact of low-carbon energy supply on remote community in the Philippines.

Customer reliability is another problem expressed by the local leaders in Cobrador. There are subscribers who are in default of paying their electricity bills. Local leaders say that these consumers tend to ignore their bills when they are still small up until their bills have accumulated and become more difficult to pay. This consumer behaviour poses a threat to the financial viability of a cooperative with limited resources and that relies mainly on customer patronage for sustainability. A pre-paid billing system could be an option to avoid the problem of unpaid electricity bills but would add extra investment costs (Kambule et al., 2018). When asked, consumers with lower electricity bills said that they do not have the financial capability to pay for an increased consumption of electricity even if it becomes available, and that they are consciously cutting down on their electricity cost.

4.1.3 Societal factors

The lack of skilled technicians relates to the novelty and complexity of RE technologies. Since these technologies are not yet often applied in remote islands, it is difficult to find experienced technicians. Additionally, technicians tend to leave rural areas to seek better income sources in urban areas after finishing their training. Skilled labourers are necessary during the construction of facilities and can sometimes not be recruited from remote islands. This lack of locally available skills entails higher cost for constructing, operating, and maintaining energy systems as EC resort to incentivizing workers and technicians to regularly go to or to move to these small and remote islands.

Officers of ROMELCO and the island residents of Cobrador discussed the difficulty of securing access to land for the construction of the power plant and its distribution cables. Most of the lands were privately owned and the reluctance of the owners to give access to their property posed a threat to the realization of the EC low carbon project. The long and tedious process of negotiations pushed ROMELCO to seek legal advice and research support which resulted to their 'discovery' of an existing law that provided for the appropriation of private lands when it is necessary for infrastructure development. This experience makes it clear that a supportive policy or legal environment while important is not sufficient to enable RE ventures in small and remote islands such as this.

While it was public clamour, which at times was violent, for cheaper and more stable power supply that instigated ROMELCO's bold move to go into power generation, proposed RE solutions were also met with resistance from the community at first. In the case of a hydro power plant in Sibuyan island (another RE project implemented by ROMELCO), the people in the area argued that the hydro project would cause the deterioration and eventual death of their river resources. It took patience and persistence in information and education work on the part of ROMELCO to finally convince the villagers about the measures they have undertaken to ensure the ecological sustainability of the hydro power project.

The local leaders and plant operators in Cobrador also narrate their experiences of having to contend with irate customers in the island when there is a breakdown in the plant or when a customer's electricity service is cut due to unpaid bills. The local leaders represent ROMELCO in the island and are therefore regarded as the village-level cooperative representative. While it is easy to dismiss this as a customer relations issue, which can be easily managed away through outsourcing, one has to bear in mind that at the village-level, these operators and customers are interwoven into networks of social relations as neighbours, extended families, or kinship based on rituals, and are locked in face-to-face interactions. The success or failure of the cooperative venture in small and remote islands would depend on the success or failure in maintaining an appropriate level of trust and cooperation among the villagers.

According to interview partners, many international donor organizations implemented projects to foster the use of renewable energies in remote areas in the 1990s. Most commonly they distributed solar home systems (SHS) to households, however once the projects were over, there was a lack of ownership and know-how of maintenance among the villagers, which resulted in the decay of the systems and villagers' distrust of RE projects.

One interview partner recommended to include influential players of the island (e.g. priests, barangay captains) in the project planning process in order to gain the trust of the villagers. Creating new job opportunities for the villagers through e.g. the construction of the site, the maintenance of the power plant or collecting the electricity bills from the various users could also facilitate social acceptance. Regular information meetings with the community and inclusion of the island residents in every phase of project implementation is crucial for community empowerment and social acceptance.

4.1.4 Technological factors

Many EC still consider the national grid extension as the main and most feasible option, even though the main grid is often far away and the connection via submarine cables is very costly (Kuang et al., 2016). This is partially due to the availability of a public fund for line expansion and submarine cables in order to eliminate the high subsidies in the long term. For off-grid solutions, most EC consider diesel-powered generation or SHS as the only alternatives. However, there are many limitations to SHS as they cannot meet the electricity demand of the households adequately, let alone electrify public entities such as schools or health centers. EC are seldom aware of the option to hybridize their existing power systems or hesitate to invest in new technologies as it also bears further risks in terms of maintenance and monetary returns. There are few local developers, most of the companies that build hybrid power plants on Philippine islands come from foreign countries such as Korea, Japan or Germany. Local engineers have to be trained to maintain new power systems and adequate incentives for them to stay rather than to seek job opportunities elsewhere would have to be put in place.

The energy project in Cobrador is a joint project with a Korean-based firm, which provided the entire technology bundle. Delays and difficulties were encountered during instances of breakdown within the warranty period as it takes a long time for repair materials and technical experts to reach the island and to do the necessary repairs. The joint venture is apparently in the framework of a turnkey agreement rather than a transfer of technology framework, which would enable local innovators to build, replicate, or replace the technology based on locally available resources and technical expertise. Instead, the local residents were trained to become operators of the imported technology bundle. The complexity of the system includes the interaction of system parts like battery, solar panels and diesel generators, which have to be synchronized. Uncertainty was formulated regarding the disaster resiliency of the low-carbon technologies, since most of their parts are directly opposed to the natural surroundings. As most small and remote islands in the Philippines are exposed to frequent extreme weather events, RE technologies that are deployed in these islands need to be designed and adapted for disaster resilience.

4.1.5 Geographical factors

Small islands in the Philippines are mostly remote. There is a general lack of reliable and appropriate transportation systems and related infrastructure to facilitate access to these small islands. The transportation of the equipment for a power plant to remote islands is often very complicated and exposed to several challenges. The current may not be strong enough, so that boats cannot run the planned schedule, which can lead to delay in the delivery of the needed materials and equipment. Additionally, the equipment is often highly vulnerable to damage and has to be handled very carefully. Many islands do not have a jetty, which means that just docking the ship to the island is a challenge itself. Transporting the equipment from the port to the site where the power plant is to be located is another effort and requires a lot of labor force. Before the transportation of the power plant material, similar challenges apply for the construction of the power plant itself. In many cases, construction materials have to be transported from a neighboring island via boat and then to be carried to the project site. The dispersion of the island population is an obstacle when it comes to connecting the houses to electricity and putting up the electricity posts. In many cases, population is highly dispersed and in order to access the houses rivers have to be crossed or houses are located on hills with poorly constructed or non-existent roads.

4.1.6 Strategies to address uncertainties and risks

This section summarises how the EC in this case study, in spite of odds, build up capability to implement a low-carbon energy project successfully. Finally, it provides lessons-learnt for the implementation of cooperative-driven low carbon energy projects in the Philippines in the future.

We consider the motivation of the EC, embodied by their staff, to realize the low-carbon energy system as a cornerstone for successful implementation. This motivations stems from a broader vision to supply the entire franchise area of the EC with RE in the midterm. First, the EC built and nurtured continued engagement and collaboration with policy makers, industry experts, and community stakeholders. Therefore, it used conferences and meetings, to share its experiences, highlight bureaucratic hindrances and put forward its policy advocacy. Second, the EC went ahead with implementation even when the bureaucratic procedures took a long time and permits were still pending. In effect, the EC shared the risk of higher costs with the community while their claim for subsidy was still pending in a government office. Although the customers were initially unwilling to pay higher tariffs than family members and friends in neighbouring islands, they concluded that it is in their own interest to pay higher tariffs if this would accelerate the implementation of the clean energy system. This was a result of information campaign and dialogues with community stakeholders to gain their acceptance and support. Third, the EC cooperated closely with international donor organizations and technology providers, which proofed essential since the project was eventually realized with grant funding. The EC harnessed the interest of technology providers to realize a proof of concept of its product for their own purpose to provide clean energy to their deprived customers. Although this cannot be a generalized model for the entire country, it contributed to building trust in RE in the Philippines since many interested stakeholders are visiting the project. Fourth, the EC looked for provisions in the law that would work in their favour and applied it when landowners resisted infrastructure projects due to individual business interests. Fifth, the EC addressed the lack of skilled technicians and labourers by training residents for operating the low carbon energy system. This was realized through investing into their staff, e.g. paying for their vocational training. This resulted in job opportunities for several villagers.

Finally, success factors and lessons-learnt for the future implementation of cooperative-driven clean energy projects can be derived. A clear development vision is necessary to ignite the motivation of an EC to advocate politically for its projects and implementing it despite of bureaucratic odds. Thereby addressing political risks and uncertainties. Cooperation with technology providers and donor organizations alleviated economic and technological risks and uncertainties. Stakeholder engagement and training of local staff builds trust and engages people, thereby addressing societal factors. While geographical factors cannot easily be addressed, the experience in Cobrador island instigated interest in developing containerized solutions for transportation requirements that would leverage the cost and labour intensive construction of power houses in the future.

5 Conclusions

Policies and regulations are important but unless implementing guidelines that make it easier for cooperatives to venture into RE generation are put into place, the policy environment will not effectively induce their active support for energy transition. This study identified the most serious

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implementation risk to low-carbon energy transition in the Philippine context, which is the discontinuity between the present administration's policy pronouncement and its policy implementation practice. A sustained and focused conversation on how to incentivize local innovation and technology to produce local parts for local resources, and to develop local knowledge and capacities to innovate, to do reverse engineering, or to design appropriate local technologies is also lacking. This is a challenge to local engineers and higher education institutions in general. It has already been recognized that managers of EC play a pivotal role in leading the transition to low carbon systems, hence they have been given numerous skills trainings related to grid planning, management, etc. What is missed, however, is that managers of EC would also need to navigate what are usually challenging terrains of local politics and power dynamics. They would need to develop the capacity to insulate themselves from vested interests and to focus on the service-oriented mission of EC. The uncertainties faced by EC who venture into low-carbon energy options in small and remote islands in the Philippines seem insurmountable at first glance. The interrelatedness of lack of access to finance and the high upfront costs for RE technologies are risks for EC in the Philippines. The hidden costs for EC for venturing into RE projects in small islands are generally ignored by an undifferentiated incentive scheme and a sluggish bureaucracy. Without a policy environment and a private sector that are unequivocal in their support and promotion of RE projects for small islands, the implementation risks are placed squarely on the shoulders of the cooperatives. EC need support in building their credibility and capabilities to promote a paradigmatic shift in financial institutions and prospective private sector investors. The pathways to low-carbon transition are marked by persistent opposition and struggles. It is equally important to recognize and pay attention to the emotional labour input of the implementers on the ground. Their ability to reflect upon their experiences and recognize their own achievements which then become their motivation to persist along the path towards low carbon and RE transition add to the resilience of low-carbon energy transition projects in missionary areas. Enabling the sharing of these experiences with other communities and leaders is an important conduit to facilitate the flow of energy that would create the critical mass of grassroots enablers towards energy transition. The pathways to low-carbon transition require a critical mass of trailblazers. The risks and uncertainties that mark these pathways are best transcended through public, direct, and participative deliberations. Because of these, EC remain as a promising pathway for low carbon energy transition.

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