

Evaluating the use of renewable energy and communal governance systems for climate change adaptation

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Abstract:

Aim: Renewable energy (RE) systems can be effective tools for rural communities for meeting goals for development and climate change mitigation and adaptation. RE systems provide small amounts of electricity fostering community development through improved energy access, livelihood opportunities, and improved quality of life. Communities in rural Guatemala are increasingly vulnerable to climate change impacts, due to increasingly extreme weather events. Distributed RE systems can be more effective than connection to national electric grids in providing power if community members have the agency and skill (technical and in governance) to maintain them. The goals of this study are to evaluate the performance of RE systems used in a rural Guatemalan community and the governance system created around, contribute to the literature on RE systems as a means for climate change adaptation, and identify further challenges in operation, monitoring, and evaluation of these projects.

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Design/Research methods: The specific RE systems were evaluated eight years ago; they had performed well especially after Hurricane Stan. Recommendations were made for further performance improvement. This study evaluates the subsequent performance given more intense rains, and the current state of related community governance on the basis of semi-structured interviews. The results of this study are compared to the ones obtained in the first evaluation carried out in 2009.

Conclusions/findings: This research highlights the need for enhanced and continuous monitoring and evaluation methods for both energy projects and their supporting institutional structures. Accountability, mediation mechanisms and transparency tools within these institutions can allow more open communication and equitable treatment with agents of power. The RE systems ultimately failed because of the arrival of the electrical grid and the failure of the governance system. Although users now enjoy more appliances, they indicate a desire to have the RE systems back as they are more reliable.

Originality/value of the article: The article provides original insights for project implementation and policy information. Strong trust bonds are necessary for community resilience in emergencies, and in the well-being and development of the community, independent of energy sources.

Keywords: renewable energy, adaptation, climate, resilience, institutions, governance, Guatemala
JEL: O10, Q20, Q42

1. Introduction

Investing in and implementing community-based renewable energy systems has been identified as a key solution to climate change as well as meeting Sustainable Development Goals (SDGs) (IRENA 2019, Ley 2017, Madriz-Vargas et al. 2018). While contributions of RE interventions for climate mitigation (through emissions reduction) and sustainable development (through improved energy access, poverty reduction, and cascading effects on education and quality of life) have been widely assessed, implications for climate change adaptation have received relatively less attention (Ley 2017, Venema and Rehman 2007). More recently, empirical evidence on the role of RE for adaptation is growing: for example, decentralized RE can facilitate disaster recovery by provision of electricity (Ley 2017), RE generation in communities can support local services such as health and water facilities, telecommunication, and enable livelihood diversification (Madriz-Vargas et al. 2018). What is less understood is how RE performance is mediated by local institutions and power dynamics and the implications of these governance structures and processes on adaptation to climate change.

While energy access across Central and South America is high relative to many developing countries, last-mile electricity delivery remains a challenge (IRENA

2018). This is where off-grid, decentralized energy systems have been identified as key to meeting energy access, mitigation of emissions, and adaptation concerns. Following global trends towards decentralized, community-based energy provision, national governments in the region have experimented with mini grids, solar energy, biogas etc. (Madriz-Vargas et al. 2018). In Guatemala, the site of this research, 67.4% of the country's energy comes from renewable sources (CEPAL 2017), with aim to raise this to 80% by 2027.¹ In the latest 'Policy for Rural Electrification 2019-2032' (MEM 2019), Guatemala's Ministry of Energy and Mines has announced a push for increasing renewable energy use, especially in rural areas, and instituting legal frameworks to integrate alternative sources of energy such as solar PV systems, wind power, small hydroelectric plants, and hybrid power plants. While this support of renewable energy is welcome, examining how existing RE interventions perform on the ground is critical to meeting these climate and sustainable development policy goals.

The adaptation literature has converged to argue that adaptation governance, i.e. the institutions, processes, agendas, and power dynamics involved in "steering action and processes" (Huang et al. 2018:223) towards local adaptation strongly mediate adaptation project functioning, performance, and sustainability (Vink et al. 2013, Huitema et al. 2016, Valdivieso et al. 2017). Moreover, the shift to renewable energy systems is not limited by technology alone but requires "collective involvement of a range of local actors and the penetration of low-carbon practices and technologies in [...] physical, economic and social systems" (Huang et al. 2018:223). In practice, this strongly indicates that careful consideration of local power differentials, and institutional arrangements and functioning, is key to adaptation intervention outcomes.

From a six country study on micro-grids based on small-scale solar across Bangladesh, Brazil, India, Mozambique, Sri Lanka and South Africa, Kumar et al. (2019) demonstrate how technological and social factors such as the flexibility/fixity of the projects and the de-/centralisation of agency critically mediate solar energy project outcomes. Using the example of environmental disaster risk management in

¹<https://www.energia16.com/58-36-percent-of-guatemalas-electricity-comes-from-renewable-sources/?lang=en>

Chile, Valdivieso et al. (2017) demonstrate how institutional dimensions such as management transparency, local government coordination, degree of public participation in decision-making processes, and vertical cooperation across governance scales can significantly improve adaptation outcomes. Assessing community renewable energy projects across Panama, Nicaragua, and Costa Rica, Madriz-Vargas et al. (2018) found that stable and long-lasting social structures to support governance of financial and non-financial benefits and shared maintenance responsibilities are vital to ensure long-term operation of RE systems. A four country study from Laos, Peru, India, and Tanzania also finds that the socio-economic context that sustainable energy projects operate within determine both project outcomes and longevity (Ortiz et al. 2012). Collectively, these studies highlight the importance of accounting for socio-institutional arrangements (in addition to technical aspects) when planning and implementing RE projects.

There is also a well-developed literature around governance of common property resources (CPR) which uses institutional theory to identify the conditions and processes through which users (individuals and groups) self-organize and govern the resources they depend upon (e.g. Wade 1987, Ostrom 1990, Agrawal 2001). Some authors have applied developments from this literature to the use and governance of RE systems (i.e. Wolsink 2012) where decentralized energy, often generated within communities, is likened to a common property resource, and its use and management, draws parallels with CPR governance.

In this paper, we use empirical evidence from four RE interventions and their related productive uses in one community in Guatemala, chosen because they explicitly aim to meet triple objectives of sustainable development, and climate mitigation and adaptation. We (1) trace how the projects evolved, with mixed outcomes for the community cohesion, and (2) identify factors that can hinder project functioning and outcomes, as well as their long-term sustainability. The paper makes three contributions. First, by examining the institutional barriers and enablers to sustaining community RE interventions, it adds to the literature on adaptation governance, specifically showcasing how community trust is critical to project functioning and outcomes. Second, by focusing on RE systems in rural Guatemala, it contributes to the empirical gap on adaptation implications of small-

scale, rural RE interventions (de Coninck et al. 2018). Finally, the findings have implications for community RE implementation and policy by identifying key challenges in operations, and monitoring and evaluation, with specific lessons for Guatemala's 2019 Policy for Rural Electrification.

2. Methods

2.1 RE projects studied

The study was conducted in a community in El Palmar, Guatemala. Located between the Pacific coast and the Western highlands of Guatemala, the community was originally a privately owned *finca* (country estate) with commercial plantations of coffee and macadamia. Due to social conflicts with the owners, the community members abandoned the ranch. Later, when the *finca* was abandoned by the previous owner's son, the community secured a loan to buy it. They refurbished the *finca* and started processing coffee and macadamia nuts, as well as adding new projects such as pig and chicken farms, purified bottled water, and an ecotourism hotel. In 2005, the community was severely affected by Hurricane Stan but was nonetheless able to provide emergency relief to surrounding communities, especially by providing purified water, as emergency and rescue operations were slow in the days after the event because access to these remote locations was difficult. As a community member stated in retrospect 'We were not isolated, 'they' were isolated from us'.

The community studied had multiple RE projects in operation (

Table 1) when first visited in 2009. The RE interventions were managed by the community and had a household-level monthly tariff system, a set of internal rules, and fines for late payment or using more electricity than allowed.

Table 1. Types of RE interventions in studied community in El Palmar, Guatemala in 2009

Type of RE intervention	Details
Micro-hydro	The original 16 kW micro-hydro plant was refurbished by the community using a grant from the UNDP Small Grants Program by installing two 8 kW Pelton turbines
Biodiesel	Average production of 48 gal biodiesel per 48 hours using recycled kitchen oil. This is was in a diesel generator to power 50 homes in the community, the finca offices, eco-hotel, and coffee, macadamia, and purified water projects. After Hurricane Stan, the biodiesel plant was supplied fuel for trucks and was especially useful to deliver potable water to nearby communities
Biogas	Piggeries, also for biogas generation which failed after rats chewed gas catchment system
Solar PV	Household solar PV which also supplied electricity for local eco-hotel
Water purifier	RE-powered water purifier for bottled drinking water from a community-owned spring sold within and outside the community
Coffee cacao and macadamia processing units	Coffee, cacao and macadamia plantations by the previous finca owners were refurbished and expanded, and coffee roasting and sorting were powered by RE

Source: Authors' own research

2.2 Research design

This research used semi-structured interviews with members of the committee that oversaw the RE systems and those who had left it. Interviews focused on the performance of the RE systems, the tariff structure and the functioning of the committee, and how micro-enterprises had evolved.

This research used a total of 23 semi-structured interviews with community members (15 in phase one and 8 interviews eight years later). The original aim was to interview the same people as in 2009 as well as those currently in charge of project management, as well as users and non-users, however, after the initial interviews it was clear there was fear amongst the community members to express their opinions. In the second phase of interviews, a particular focus was put on the performance of the RE systems in the most recent tropical storms and hurricanes, the

losses the community has incurred, and other climate change adaptation mechanisms applied (early warning systems, communications during emergencies, use of shelters, use of purified water for themselves and other communities, amongst others). We aimed to assess the performance of RE systems through number of days with blackouts, extent and number of repairs done in a year, frequency of preventive maintenance, whether people were hurt due to operation and maintenance tasks, and number of days the RE systems failed to function during extreme weather events. However, given that the systems were defunct when the site was revisited during the second phase of interviews, we could not carry out an assessment using the above inspection protocol.

The first phase of this study took place in 2009 where the research team spent two weeks in the community conducting interviews with the community leaders, people in charge of each productive use project, a women's group, and RE users and non-users. We also undertook a technical inspection of the PV, hydro, biodiesel systems, and provided recommendations to potentially add to system and institutional robustness. A second visit in 2017 was then undertaken to assess the longer-term impacts of the RE projects, focusing on whether the community had been strengthened, the evolution of the governance mechanisms that had been institutionalized, and how the projects had evolved in terms of robustness during extreme weather events (following recommendations we had provided them), growth of other productive use projects, and expansion of hydro and solar PV systems. Interviews were conducted with the former community leadership, some of the workers of the micro-hydro and project managers and other community members. We also spoke to people external to the community who were familiar with or had formerly assisted with O&M of the micro-hydro project.

Data collection was challenging and interviewee selection purposive because many people were wary of discussing the performance of the RE projects. In many cases, respondents articulated feelings of fear when discussing the project, possibly because of not wanting to be seen as reporting negative impacts that might affect their relations within the community and fear of retaliation by former community leaders who were still influential.

3. Findings

The RE project studied began as externally funded but community governed interventions with careful attention paid to issues of participation, equity, and capacity building (Table 2).

Table 2 Governance characteristics of the RE project

Project characteristics	Details	
Roles	Funding entities	Various: Multilateral development organizations and local university
	Development entities	Community
Governance characteristics	Type of governance structure	Committee within the community, with well-defined roles and responsibilities that were followed
	Rules and regulations	Well-defined though not everybody followed energy usage regulations
	Community participation	Yes
	CPR management	No
	Training	Community received administrative, technical training
	Tariff structure	Yes, but not sustainable
	Equity	The project outcomes were equitable to an extent. Some elite capture by community leaders (e.g. over use beyond allotted energy quota) and women's group reported losing power when the UNDP project ended
Adaptation	<ul style="list-style-type: none"> ✓ Energy provision for livelihood diversification ✓ More assured energy supply, especially during extreme events 	
Mitigation	<ul style="list-style-type: none"> ✓ Energy savings ✓ Emissions reductions 	
Sustainable development	<ul style="list-style-type: none"> ✓ Domestic uses ✓ Productive uses ✓ Communal uses ✓ Cost savings ✓ Social acceptance (for some time) 	

Source: Authors' own research

However, the observations made during the second visit of the community and the statements taken by the different community members very clearly revealed a number of factors that contributed to the demise of the RE project. These are detailed in the subsequent sections.

3.1 Mismatches in community needs and RE project deliverables undermined operations and maintenance

With respect to energy access, the micro-hydro plant was observed to be poorly engineered and constructed during a technical inspection during the first phase of this study, and its capacity was insufficient to meet the community's demand for electricity. As a result, people had been eager to connect the community to the national electric grid in order to use more appliances in their respective households, and worked collectively towards that end. Eventually, community efforts to connect to the national grid succeeded. As a consequence, the community started paying the required tariff to the utility and there were no more payments to the community maintenance team for the upkeep of the hydro facility, which subsequently fell into disrepair. This was compounded by internal conflicts and mistrust within the community (detailed in Section 3.3).

During the first phase of the study, there were reports of some households consuming more electricity from the micro-hydro than allowed by the tariff and agreed-upon project rules, leading to conflicts within the community. Each home had a meter and a 'lock'; when a household exceeded its allotted consumption, the fuse would burn, cutting off electricity supply to the household, which would only be restored after paying a fine. Despite this, some people, typically community leaders, were using appliances specifically disallowed by project rules such as big color televisions and laptops that drew more electricity than was allotted.

Even during the first phase of the study, the community planned to connect to the national electric grid when available. The hydro facility would be kept as a back-up for grid electricity in case of disruptions due to extreme weather events (Ley 2013), which were evidently not factored in the community's decisions to abandon the RE projects as observed in the second phase of the study. Thus, community decision-making was seen to be dominated by "short-termism," a lack of awareness

of or low value ascribed to the multiple benefits of the RE systems (e.g. improved resilience in the face of extreme weather events), and internal conflicts. Other studies have also noted that funded by international aid agencies, and lacking a broader enabling governance environment, community renewable energy projects across Central America have been plagued by issues of remaining functional for only a limited time (Madriz-Vargas et al. 2018).

3.2 Project failure exacerbated community vulnerability

In terms of adaptation to climate change and the community's conditions with respect to energy supply, our observations and the results of the interviews clearly demonstrate that the community's vulnerability to impacts has been greatly enhanced by the failure of these RE projects. As expected, as the community is situated within the last kilometer of a distribution line, people are subject to many blackouts. Further, the terminal portions of distribution lines tend to have more voltage fluctuations that can cause brown-outs or burn appliances. During the rainy season, when people most need electricity – especially in cases of emergency – they are actually cut off, sometimes remaining without electricity for up to four days continuously. Since the hydro facility does not function anymore as a back-up, there is no other way of acquiring electricity in this case, which means that there are no radio communications, means to charge cellular telephones, or other means of communication during emergencies. However, a few relatively wealthy (by community standards) households have solar photovoltaic installations that allow those individuals very basic levels of electric service.

From the interviews in the second phase, there was unanimous agreement that people would prefer to have the hydro facility, which people testified to having been more resilient. While they viewed the hydro as more resilient, they acknowledged its lack of capacity had been problematic before the arrival of the electric grid. Many homes have refrigerators to sell or store cold products including beer, soft drinks, meat, etc., and they lose products during these blackouts, which makes them lose income, exacerbating their vulnerability. Because of the lower capacity of the hydro, community members did not use refrigerators when the hydro provided all of the community's electricity. Thus, while the grid provided an increased opportunity for

earned income (e.g., storing meat to sell), it has also increased their vulnerability due to the frequent and prolonged power failures.

3.3 Trust as key to community participation

Trust is paramount to effective communal governance of external interventions (Walker et al. 2010) and the lack thereof can lead to the deterioration of an RE system, independent of its technical robustness, as was the case in the community visited. When the RE systems were functional, community members faced loss of power only occasionally. A respondent emphasized, *"We used to be able to cope better during storms, with the grid, when the light goes off it takes at least 4 days before we get light again"*. One woman respondent who owned a small shop selling ice creams and cold drinks added, *"The grid is very unreliable. I miss the hydro power...especially for my business...if there is no electricity, most of my popsicles just melt."*

One of the arenas where community conflicts played out was the coffee processing unit. Typically, members sold raw coffee beans to the community leader who oversaw bean roasting and grinding. However, the rates the leader offered were low and in parallel, some families found other middle men to buy their raw coffee beans, earning a bit more than what the community concession was paying for the communal product. This resulted in the general perception that the community leadership was keeping money for itself and cheating the community people. Subsequently, trust among the community began to erode and with that the motivation of maintaining the projects decreased, until they were ultimately abandoned and common property even became subject to looting. We found that conditions related to community cohesion but not directly related to the RE projects deteriorated in tandem with the institutional structures surrounding the projects. As an example, the community used to have a "communal fund" for celebrations, emergencies, and to help those in need. After the loss in trust over the coffee business described above, this practice was abandoned, leaving the poor and elderly on their own facing up to the impacts of extreme weather events.

These findings echo other studies that demonstrate that "trust (has) a necessary part to play in the contingencies and dynamics of community RE projects and in the outcomes they can achieve" (Walker et al. 2010: 2655).

4. Discussion and conclusion

This paper has added to the literature on adaptation governance by identifying community trust as a critical enabling factor of project functioning and outcomes. In particular, this research highlights the need for enhanced monitoring and evaluation methods and their continuous implementation for both the renewable energy projects and the institutional structures that surround them. It also emphasizes how including mechanisms for mediation in these institutional structures is necessary to ensure project sustainability. The renewable energy systems evaluated had been exemplars of the use of these systems to adapt to climate impacts but failed due to mistrust and unresolved disputes, highlighting the importance of having mediation mechanisms and transparency tools that will allow for more open communication and level the playing field with agents of power.

The findings point to the need for trust within individuals and institutions and the need for regular monitoring, evaluation, and mediation for projects to deliver their stated outcomes and increase resilience. Having these mechanisms will help ensure that problems are dealt with as they arise so the RE systems will work as expected during extreme weather events or other emergencies. First, developing and maintaining strong trust bonds are necessary for acceptance of the project in particular and community resilience during extreme weather events in general. Second, having robust, multi-scalar monitoring and evaluation processes can help identify potential negative or unintended impacts as well as plan for potential failures. As other research has pointed out (Ortiz et al. 2012), the lack of monitoring and evaluation have led to the failure of systems even in cases where there were small technical or social issues.

At first sight, these findings are difficult to reconcile with the literature on collective action theory, which spans the spectrum from Ostrom's (1990) work on poly-centric governance of collective resources to Hardin's (1968) call for state control. While initial project performance pointed more towards the success of community management, the subsequent performance might be interpreted to

indicate that polycentric governance has not been sustainable and that project management should have been handled centrally. However, looking at some of the empirical work in this area, it quickly becomes clear that there is also a grey zone in between Ostrom and Hardin: In particular, Wade (1987) concludes from his work in India that users will fail to come up with effective rules of restrained access to collective resources if or when there are many users, when the boundaries of the common property resources are unclear, when the users live in groups scattered over a large area, and when undiscovered rule-breaking is easy. The research presented in this paper actually points to a variation of Wade's last item on rule-breaking as the reason for governance failure. In particular, the rule-breaking was not undiscovered, but it still undermined effective and sustainable governance, as there was no accountability once it was perceived. Thereby, this study's findings do not invalidate the case for polycentric governance, but rather specifies circumstances which have to be met in order for community management of common-pool resources to be effective and sustainable.

The paper has also contributed empirical work on adaptation implications of small-scale, rural RE interventions (de Coninck et al. 2018). The study shows how community RE can contribute to adaptive capacity through:

- building disaster resilience (as seen when energy supply helped during Hurricane Stan)
- diversifying livelihoods (e.g. into eco-hotels), which contribute to household incomes
- reducing community reliance on external energy sources thereby improving self-sufficiency (the grid was neither reliable nor robust and even though the hydro power plant had problems, it was more reliable than the grid and was under the control of the community).
- Improved communications (the RE energy also enabled charging cellphone batteries, particularly critical during extreme events)

Finally, the findings presented in this paper have implications for community RE implementation and policy by revealing challenges in operations, monitoring and evaluation, with specific lessons for Guatemala's 2019 Policy for Rural Electrification. Key to project implementation and sustainability, is reconciling

community needs and demands with project deliverables. This also includes considering community expectations and their perceptions of RE projects *before* implementation. The study also found that following safety and quality codes and standards, as well as providing adequate training to ensure nobody gets hurt during O&M is critical for the technical functioning of the project. When safety protocols are breached, they can undermine human safety (through accidents) and the RE system’s reliability, which, in the long-term, can erode community trust in and reliance upon the RE system. As the study showed, when investing in an RE system, setting up RE generation is not sufficient: developing institutions that are transparent is key to effective community RE systems. While the project studied did ensure transparency in the early years (through proper records), these practices fell away and had completely eroded when we visited eight years later.

Table 3 Aspects of resource governance theory found in Guatemalen RE projects

	Aspects of resource governance	Findings from community RE project in Guatemala
Ostrom (1990)	Renewable energy resource system characteristics	✓ Well-defined boundaries
	User group characteristics	✓ Well-defined boundaries
	Relationship between resource system and users	✓ Energy consumption limits exceeded
	Institutional arrangements	✓ Locally devised access and management rules
		✓ Easily enforced rules
		✓ Graduated sanctions
		✓ Availability of low cost adjudication
		✓ Accountability of other officials to users
	Relationship between resource system characteristics and institutional arrangements	Good
External environment	✓ Technology (RE) system helped meet development goals and strengthen management skills	
	✓ Central governments should not undermine local authority	
	✓ Nested levels of appropriation, provision, enforcement, governance	
Wade	Low-cost exclusion technology	

(1987)	facilitates management of CPRs
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Source: Authors' own research

The main limitation of the study is that only one community was evaluated in this manner, so a comparative study with other communities with RE systems is desirable and an important area for future research. Further conditions that relate to the potential for transformational adaptation (such as behavioral or technological aspects of efficient use of energy) were excluded from this work but should also be considered. As with any communal project, the local contexts need to be taken into account.

Overall, community RE systems are a key strategy to meet climate mitigation, adaptation and sustainable development goals. Targeted at communities, decentralization and participation are core to the functioning of community RE. Using a case of Guatemala, we show RE project sustainability is strongly mediated by community dynamics and internal trust. Recognising how social dynamics interface with technical aspects to shape RE project outcomes is a necessary first step to effective community RE.

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EVALUATING THE USE OF RENEWABLE ENERGY AND COMMUNAL ,,,

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