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The future of Community Renewable Energy for electricity access in rural Central America

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ABSTRACT

When a Renewable Energy (RE) power system is owned, operated or maintained by a community organisation, some of the problems associated with other rural electrification implementation models e.g. private or utility, can potentially be solved; including: lack of utility investment, barriers relating to social integration of RE technologies, lack of local maintenance capabilities, and end-user education. However, a range of challenges for community-based energy initiatives in developing countries are identified in the literature, often compromising the long-term operation of RE technologies and the sustainability of the project as a whole. Hence, questions arise around the set of community capabilities required, appropriate project design, and enabling external environment for sustainable Community RE (CRE) projects. Relatively longstanding CRE rural electrification experiences in Central America can offer useful insights on the challenges, capability requirements, and future perspectives for further deployment and governance of CRE initiatives in the developing world. In this study, a comparative analysis from case studies across Panama, Nicaragua and Costa Rica was undertaken after field investigation conducted over eight months. A cross-disciplinary method combining qualitative social research and techno-economic analysis of RE power systems was then used for data integration and sustainability assessment of selected case studies.

1. Introduction

Achieving universal access to electricity remains a pending task for national governments and industry. By 2014 over a billion people worldwide were living in off-grid conditions [1], mostly in rural areas of developing countries. According to experts, this situation will still affect nearly 500 million of the world population by 2040, even if optimistic rural electrification scenarios become a reality [2]. Electricity provision in isolated rural communities can result in significant socio-economic outcomes. For instance: supporting humanitarian aid [3,4]; improving education [5,6]; improving health services [6,7]; improving drinking-water provision [8,9]; enabling gender and youth empowerment [10–12]; and allowing productive uses resulting in poverty alleviation [13–18].

Rural electrification in developing countries can be realised via grid-extensions, minigrids or stand-alone power systems. Unfortunately, many utilities are failing to provide reliable services [19] and many are struggling financially [20,21], limiting options to expand distribution networks. As a result, there is increasing interest in electrification solutions in which Community Renewable Energy (CRE) models can play a role in providing access to modern energy services for the poorest.

Minigrids and stand-alone systems are often cheaper and more reliable than grid extensions, for example: where there is low population density and electricity demand; where the terrain is difficult and the region is prone to severe weather events; and where social conflicts exists. Experts have estimated that deployment of minigrids and stand-alone systems to serve off-grid communities can supply more than 50% of the additional technical capacity needed to reach universal energy access [19,21]. In addition, some authors have found that adoption of renewable energy (RE) technologies in isolated rural communities can result in significant socio-economic outcomes; see Section 2.1.

Nevertheless, minigrids and stand-alone systems are still seen as unattractive to private companies and utilities [22]. Most current pilot projects have been nurtured by the aid sector and international institutions [20,23], but have mainly benefited a small number of communities and only for a limited period of time. As a consequence, community-based ventures are often the only option for many rural off-grid people to access electricity for enduring community services and productive uses. Indeed, some donors have recognised the importance of promoting rural development led by the community [24,25] as an

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appropriate approach when renewable energy is to be implemented in remote areas of developing countries. This has been demonstrated, for instance, in Nepal, Bangladesh, Sri Lanka, Kenya, Burkina Faso, Bolivia, Peru and Costa Rica [26–30].

Interestingly, when (RE) systems are owned, operated or maintained by a community organisation, either totally or partially, communities can potentially overcome some of the problems associated with other electrification models, including [20,31]:

- lack of utility interest and investment
- barriers relating to social integration and acceptance of RE technologies
- end-user education and after-sales services
- lack of local maintenance capabilities.

Hence, CRE can be a driver for: greater energy autonomy and security [32–35]; building social capital [36,37]; and pursuing sustainability objectives [38–42], e.g. goal 7 of the United Nation Sustainable Development agenda. In addition, CRE can complement national agendas to support provision of electricity for disadvantaged populations and contribute to the transition to decentralised RE, as discussed in this special issue of energy futures, for the cases of India [43], China [44], the Philippines [45], Thailand [46], Argentina [47] and Mauritius [48].

However, there is also evidence of a range of implementation issues for CRE initiatives, often compromising the long-term operation and project sustainability as a whole [4,49–54]. Hence, questions arise around the enabling environments and the set of community capabilities required for sustainable CRE initiatives. Thus far, experiences have been mixed and CRE approaches have not been universally successful [3,31,55]. Moreover, some practitioners have highlighted the need for more field evidence from CRE cases studies [22,51], particularly from successful ones [56]. A lack of accepted metrics for monitoring and evaluation of CRE projects [31] hampers evaluation, including of sustainability and effectiveness in relation to project goals.

Because different stakeholders have different views on what is of importance and should be measured [30,57], cross-disciplinary methods combining qualitative social research and techno-economic analyses may be useful to bridge current knowledge gaps [58]. CRE projects involve often poor remote communities managing relatively complex and unfamiliar technology with limited resources, and many of the factors associated with project failure are related to capabilities (skills, knowledge and resources) [31,59]. Thus, an assessment approach considering local capabilities may be particularly useful for CRE projects. This way we may better understand technical and non-technical relationships between RE technology, the services provided, and the outcomes derived for end-users at community level [16]. Consequently, a new sustainability assessment framework using capability theories and based on an extensive CRE literature review is adopted in this research; see Section 2. This framework serves as a theoretical basis for evaluating CRE initiatives implemented in rural areas of developing countries.

Additionally, we identify Central America as a largely neglected subregion by international energy access researchers, as opposed to other developing regions, such as: developing Asia, the Pacific Islands or Africa. The current status of electricity access in rural Central America provides evidence of future opportunities for a broader adoption CRE ventures. There are community-based cases in Panama, Nicaragua and Costa Rica, considered worthy of analysis because they have been acknowledged by some national and international institutions as positive experiences. A brief description of the selected cases is provided in Section 3.

This study, therefore, aims to derive new insights from successful CRE ventures found in Panama, Nicaragua and Costa Rica. The overall research question is: What are the community capabilities required to implement a CRE initiative sustainably under different contexts in rural Central America? The main results from this investigation are shared in this special issue, serving to contrast the aspirations for energy futures for the global south [60] with field evidence of realities in rural areas of developing countries. In particular, the key factors for the success of energy systems, the current challenges, and capability requirements, related to the local communities in three countries aforementioned; see Section 5. By using a defined framework to analyse relevant CRE projects we also aim to provide baseline information to facilitate future theory building and knowledge exchange among stakeholders. Lessons learnt and empirical insights described in Section 6 are expected to support decision making processes by community activists, energy policy makers, implementers and regulators, as well as by energy access experts worldwide.

We believe that there are opportunities for achieving affordable and sustainable access to electricity for the poorest in Latin America and the Caribbean, sub-Saharan Africa, the Middle East and the Asia-Pacific if a more ambitious adoption of CRE is embraced; while securing electricity supply to drive local sustainable development. Additional recommendations and future perspectives for rural Central America are discussed in Section 7 to promote further debates and comparatives studies in this growing research field.

2. Background on CRE and the assessment framework

This section presents a review of CRE literature followed by a brief description of the framework employed to evaluate critical community capacities in the selected case studies, as shown in Section 3.

2.1. Community Renewable Energy literature

The existing body of published literature on CRE aims primarily to track the growing role, obstacles and benefits of community driven initiatives in the implementation of renewable energy technologies. These references are not meant to be exhaustive, but rather highlight relevant research on CRE that may benefit future studies.

Some of the relevant topics explored around CRE include [61–75]: social acceptance of renewable energy systems; governance of benefits derived from energy projects, e.g. revenues or subsidies; and ownership conflicts associated with hardware and energy infrastructure. Also, the value perceptions of energy services to the society and end-users have also been studied in [26,76].

The existing literature focuses mainly on experiences in industrialised countries [58]. In particular, promoted by academics from the UK [75] with extensive work by Gordon Walker and colleagues [36,63,64,67–69,77–79]. Further, there are studies on large and medium wind and solar PV farms via electric cooperatives in other European countries, e.g. Denmark and Germany [80–87]. North American researchers have also reported on rural electric cooperatives in the US [26,88,89], as well as the challenges for energy provision to aboriginal communities in Canada [89–94]. More recently, academics from Australia have focused efforts on the potentials and benefits from CRE in the local context [95–98] for further adoption of distributed energy using Solar PV and Wind technologies in cities, and even for going off-grid in a self-sufficient manner.

On the other hand, CRE research in the developing world is very limited. Most accounts come from international institutions and donors, mainly focused on case studies from grid extensions, minigrids, standalone systems for village facilities, and to a lesser extent, for central charging stations with battery banks. Notable institutions publishing in this area include the Alliance for Rural Electrification [99–101], Practical Action [15,22,102,103], Wisions [51], and the IEA [7,104,105]. From the donor side, some examples are the World Bank [21,30,106,107], EU aid [108], and GIZ [109,110]. However, most of the information published on CRE for rural electrification is related to initial stages of project planning and implementation. There is little empirical evidence on success or failure in later stages, where the