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A Cross-case Analysis of Needs, Barriers and Opportunities from Community Renewable Energy Projects in Central America

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Abstract
Community Renewable Energy (CRE) projects from Central America can offer useful insights for further deployment of CRE for energy poverty alleviation in developing countries. Hence, an analysis of local capabilities supporting decision making processes, as well as common needs, barriers, and opportunities from CRE projects in Panama, Nicaragua and Costa Rica are presented after fieldwork conducted for 8 months in 2016. Findings highlight that the main needs and barriers are more related to legal, organisational, and political aspects rather than social, technical or environmental ones. Additionally, there are now opportunities for strategic planning, design, and supportive policy arrangements for new CRE initiatives, given the increasing availability of modern rural electrification technologies. Results from this study may help to inform policy making, support practical knowledge exchange, and create bridges for future research between CRE stakeholders across developing regions.

1. Introduction

The absence of access to electricity has been highlighted as a key factor in perpetuating poverty in developing countries (Paleta, *et al.*, 2012). Energy poverty[1] is an issue that still needs to be tackled to enable socio-economic development, particularly in rural areas. Hence, a target of the United Nation's Sustainable Development Goal 7 is to ensure access to affordable, reliable, sustainable and modern energy for all. However, experts have estimated that, even under optimistic scenarios, there will be over 500 million people worldwide living in the same conditions by 2040 (OECD/IEA, 2016, REN21, 2017).

Sustainable provision of modern energy services is especially challenging for communities living in remote areas. Here, local governments and the local Renewable Energy (RE) industry are typically less engaged with provision of electricity for the poor. Most projects to increase electricity access levels in off-grid areas in developing countries are therefore led by donors and international institutions. While these projects are usually reported as successfully implemented, after commissioning the reality is often different (Canessa, *et al.*, 2014, Terrapon-Pfaff, *et al.*, 2014).

Community Renewable Energy (CRE) initiatives can play a role in alleviating energy poverty and complement the rural electrification efforts of utilities, donors and governments, which often struggle financially and politically to achieve energy access and RE targets. CRE research (Bomberg and McEwen, 2012, Madriz-Vargas, *et al.*, 2015, Walker and Devine-Wright, 2008) shows that when an RE power system is owned, operated or maintained by a community organisation there are direct socio-economic benefits, particularly around the energy nexus with other sectors, such as water, education, and health. CRE approaches can also help to overcome some of the challenges associated

[1] Energy poverty is variously defined as percentages of earnings spent on electricity, numbers of litres or kilograms of fuel use by households, or even as a minimum of use for covering basic family needs, e.g. 120kWh per year (Sovacool, 2014).

with other energy project ownership and implementation models, such as utility and private business (Franz, *et al.*, 2014, Madriz-Vargas, *et al.*, 2015). Therefore, promoting CRE models is potentially an important means to achieve energy access goals, as well as broader development agendas.

Nevertheless, previous studies have reported a number of technical and non-technical shortcomings in community-based energy projects (Madriz-Vargas, *et al.*, 2015, Rae and Bradley, 2012, Terrapon-Pfaff, *et al.*, 2014, Walker, 2008). In summary, it is common to observe operational sustainability issues in these types of projects within a couple of years due to factors including: low sense of ownership and project acceptance by locals; low engagement and abandonment by external stakeholders after implementation; loss of capabilities built in previous stages of the project; and lack of supportive policy instruments.

Given the important role of CRE initiatives, securing their long-term sustainability is vital and obviously requires suitable engineering design and planning, along with appropriate models for operation, maintenance and management beyond the project execution period (one to three years), where project resources tend to be focussed, and throughout the whole technology/service lifetime of 20-30 years.

Studies on CRE experiences with decades of continuous operation are rare in the body of texts and their absence has been highlighted as a key barrier to improving CRE sustainability (Bhattacharyya and Palit, 2014). This paper, therefore, aims to provide insights from three relevant CRE projects in Central America; see **Section 2**. For the analysis, we used a framework around community capabilities derived from the CRE literature, along with common needs, barriers and opportunities observed. As described in **Section 3,** an extensive fieldwork was conducted in Panama, Nicaragua and Costa Rica, with results from the Central American context briefly presented in S**ection 4**. Some final remarks and general lessons learnt are discussed in **Section 5,** which may offer insights for energy access experts and community activists in the region and more broadly.

2. Background on case studies

Three CRE initiatives in challenging rural conditions that have been recognized locally as positive examples of RETs implementation via community-based models are used as case studies. These are (see also **Figure 1**): Coopeguanacaste in Costa Rica (Madriz-Vargas, *et al.*, 2016), Aprodelbo in Nicaragua (Madriz-Vargas, *et al.*, 2017a) and Boca de Lura in Panama (Madriz-Vargas, *et al.*, 2017b) which are briefly described as follows:

- *Coopeguanacaste*- is a rural electric cooperative responsible since 1965 for grid extensions to reach remote communities in the Nicoya Peninsula, in the Guanacaste province, Costa Rica. Coopeguanacaste currently works with nearly 3 700 km of distribution network (24.9kV) serving over 73 000 connections, and also with a social SHS program for off-grid households. Operations over five decades have been supported by a local utility, banks, training institutions, and by a consortium of rural electric coops in Costa Rica.
- *Aprodelbo*- is a not-for-profit organisation created by local leaders representing different sectors in San Jose del Bocay, Department of Jinotega, Nicaragua. Aprodelbo is responsible for a 185 kW micro hydro minigrid built in 1994, now operating in both off- and on-grid modes with around 55 km of distribution network (24.9kV) serving around 2000 connections, and with an additional Solar PV Home Systems (SHS) program for the most isolated households. This project has been supported by a local NGO, the Ministry of Energy and Mines and international solidarity groups, also with technical and financial assistance from North American and European countries for over two decades.
- *Boca de Lura-* is an off-grid PV-Wind-Battery hybrid stand-alone system installed in a local school in 2011. It serves as a community centre for around 160 people in the community of Boca de Lura, in the Cocle province, Panama. It is operated by a school parent association and supported by a local university and the Ministry of Education.

Boca de Lura	Aprodelbo	Coopeguanacaste
		
2.17 kW PV-Wind-battery hybrid Off-grid stand-alone power system	185kW micro hydro with network of 24.9kV On/off-grid plus a social SHS program	Grid extensions with network of 24.9kV On-grid plus a social SHS program
Governed by a School Parent Association	Governed by a not-for-profit local organisation	Governed by a rural electric cooperative

Figure 1. CRE case studies from Central America

3. Research design

The overall methodology to conduct this investigation consisted of two main stages. Firstly, a CRE literature review revealed that the presence of specific skills, knowledge and resources in isolated off-grid communities critically influences long-term system and project survival. An assessment framework was developed using capabilities theory to observe the relationships between the management and use of the RE technologies within the energy project across six vital dimensions, as shown in **Figure 2** (left), and the community energy service outcomes and impacts on end-users and external stakeholders. The framework also permits the evaluation of decision-making processes and interactions between the internal and external environment (i.e. between community leaders and non-community actors). Detailed explanation of the development of the assessment framework will be presented in a forthcoming publication by the authors.

Secondly, an empirical research was undertaken for 8 months from March to October 2016. This allowed the completion of three case studies (**Section 2**) where the framework was used to guide technical analysis of RE power systems and qualitative data collection in parallel. Data was obtained using different tools during visits to the communities, as shown in **Figure 2** (right).

Integration of technical and non-technical observations of interactions between locals and outsiders influencing the project allowed appraisal of the capabilities built, as well as evaluation of current challenges, barriers and opportunities for wider adoption of CRE in the Central American region, as later discussed in **Section 4**.

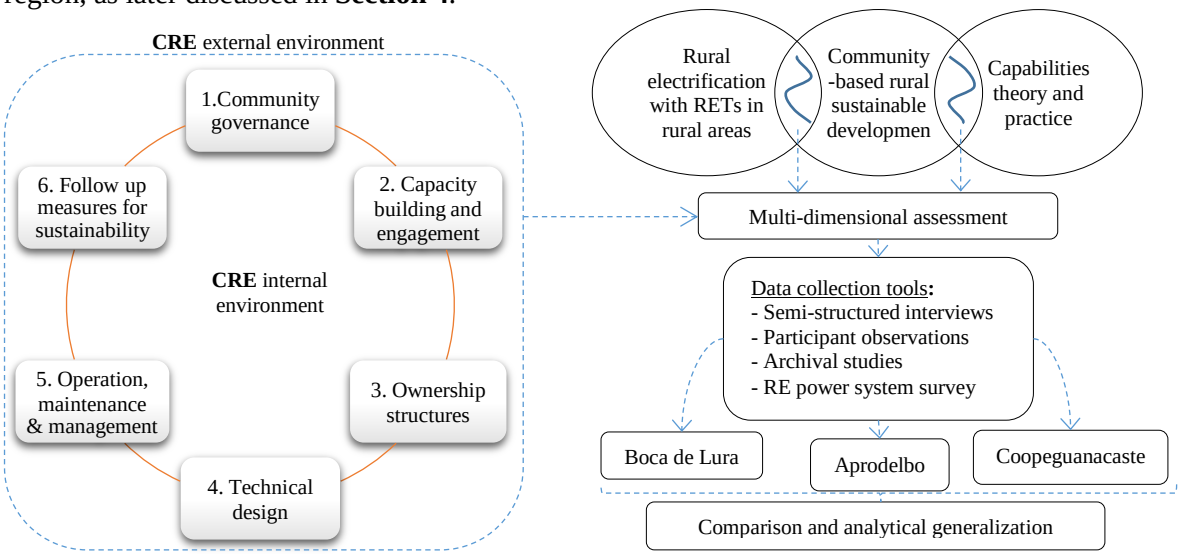

Figure 2. CRE assessment framework (left) and fieldwork methodology (right)

4. Assessment results and discussion

Specific assessment results for each case study have been published recently by the authors, for Coopeguanacaste see (Madriz-Vargas, *et al.*, 2016), Aprodelbo (Madriz-Vargas, *et al.*, 2017a) and Boca de Lura (Madriz-Vargas, *et al.*, 2017b). In this paper, therefore, the focus is on commonalities and differences observed during the field research. First, capability requirements built through the project are discussed in **Section 4.1** and compared in **Figure 3**. Second, current needs, barriers, and opportunities are briefly described in **Section 4.2**, and also summarised in **Figure 4**.

4.1. Community capabilities

Local capabilities - abilities to perform a variety of tasks to support CRE project implementation - are typically weak or non-existent in rural communities. Across the case studies, it was noted that capabilities created within social organisations and among leaders in charge of the initiative played a pivotal role, particularly to establish or maintain relevant activities or processes involving interaction with external people or organisations. These interactions later yielded useful input and yet supported self-governance, usually locally-led.

For instance, the generation of governance capabilities was observed in the building of skills including: leadership; convocation of community members to have general assemblies (sometimes held on the streets as in Aprodelbo); fundraising; and handwritten minute-taking. These skills were put to work to establish adequate channels for mobilization of shared resources, promoting democratic decision-making with active participation of women (observed in all cases). Consequently, more participative choices were possible which supported acceptance of the RE project as a whole, as well as implementation of energy efficiency measures at community level for load management.

Another relevant aspect to take into account is the time needed for acquiring the capabilities shown in **Figure 3**. From the interviews, it is clear that only over some time were these skills fully developed to the point that the community could control the project with confidence and independence. For example, in Coopeguanacaste, local management of grid extensions was possible after a couple of years of working side-by-side with external organisations, but technical abilities were consolidated only after 5 years. In the case of Aprodelbo, the project was immediately handed over to the community after construction of the minigrid, but it took 3 years to be formally operated by locals. In contrast, Boca de Lura still has pending work on the technical aspects regarding the hybrid plant as no local technicians have been trained in the 6 years of almost 24/7 operation; however, end-users consider other areas are working satisfactorily.

It is clear that capacity development should be prioritised in project planning and design, and the time needed for this should not be underestimated in order to reduce the risk of project failures or disengagement of locals. Similar finding were also reported by Terrapon-Pfaff, *et al.* (2014) after a follow up of over 20 RE community-based projects where critical situations were observed within a period of 2-8 years, and by Smillie (2000) after decades working in the donor sector in developing countries.

The field investigations provided information on the operational sustainability of each CRE venture. Long-term technical operation of RE power systems appears to be possible with ad-honorem support from civil organisations, NGOs, and tertiary institutions, which was observed in all cases. Moreover, the high levels of "passion" by project implementers (all cases) and employees (Aprodelbo and Coopeguanacaste) have boosted the levels of engagement of locals in the energy project from the outset. Further, public recognition by ministries and international institutions has promoted a positive environment and interest in supporting these projects, allowing opportunities for implementing survival measures through time.

Additional capabilities found to be required across the CRE case studies are summarised in **Figure 3** and presented according to assessment dimensions shown in **Figure 2** (left).

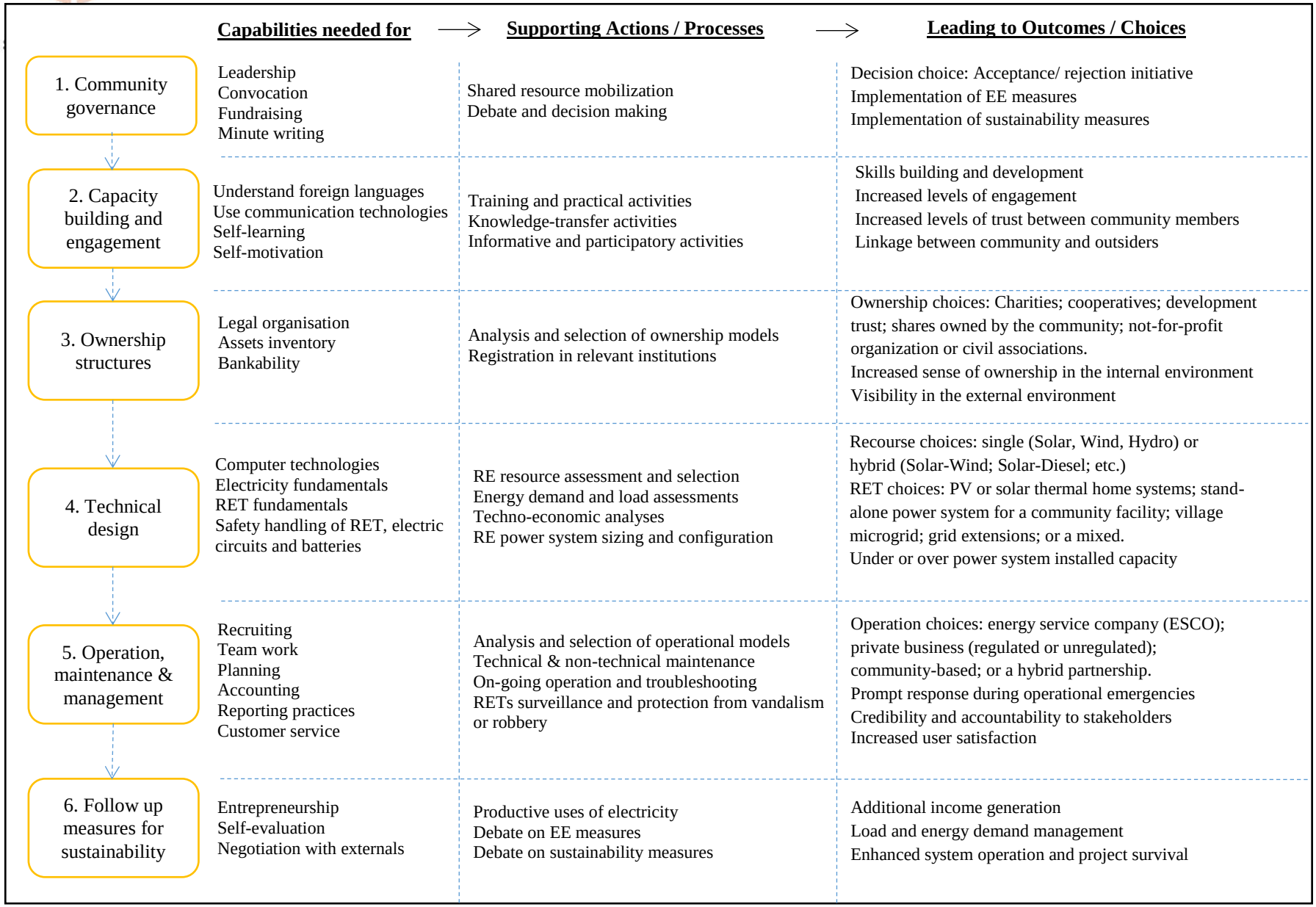

Figure 3. Capabilities found in CRE projects from Central America

4.2. CRE needs, barriers and opportunities

As mentioned, overall sustainability perspectives for the three CRE cases were found to be positive; however, they are not without barriers. Common needs, as well as opportunities have been collated from the case studies and reported in this section; see also a summary in **Figure 4**.

4.2.1 Needs: (six essentials aspects to consider for project and RE system design)

- *Local leaders involved must be recognised members of the community to ensure democratic governance of the energy project and its outcomes*. This way, the best interests of locals are taken into account during decision-making, and decisions can be better understood by other members. This was observed in all three case studies. In Coopeguanacaste a new board is elected every year and only energy meter owners from local communities can participate in this process. In Boca de Lura almost all school children belong to the locality, hence most families are also members of the parent association that governs the power system. Likewise, Aprodelbo have had a semi-permanent board with local members from San Jose del Bocay. These local institutions are generally viewed as legitimate and trusted to make collective decisions.
- *Capacity rebuilding and wider involvement within the community are essential*. Constant training and regular participatory and engagement sessions throughout the project lifetime are fundamental because of regular migration of technicians to cities, implementation of new policies and regulations, technological upgrading of RE power plants, and generational change within the community. While commonly reported in energy access programs, continuous capacity rebuilding activities in Coopeguanacaste and Aprodelbo over decades have avoided these issues.
- *Legal ownership of RE technologies, system components, and related infrastructure must be kept within the community*. New or already existent social organisations need to make the necessary arrangements to be formally recognised in order to: receive private donations; access funds from donors and embassies; formalise documentation related to transference of assets; be eligible to hold insurance; and lead fundraising activities. This was possible in Coopeguanacaste and Aprodelbo, but for Boca de Lura ownership remains only symbolic as the RE hybrid plant is located in a public school, leaving the community vulnerable.
- *External advice for RE technology selection, sizing, and configuration is commonly needed*. Without specialist technical capabilities within the communities, design criteria selected by trusted outsiders have been necessary and usually included: selection of high quality and maintenance-free system components; sizing including future demand growth; prioritising robust configurations; and budget compliance for installation, commissioning, and training on basic maintenance and safety for end-users.
- *There is a need for stable and long-lasting external support for locals to perform O&M tasks*. For Coopeguanacaste, a local utility and a brotherhood of rural electric coops in Costa Rica and in the USA have made this possible. For Aprodelbo, support is mainly provided by a Nicaraguan NGO; and for Boca de Lura this is done via a public university in Panama. In all cases, this permanent support has allowed: a) better negotiations with suppliers; b) mobilisation of financial and non-financial resources for O&M; c) coordination of shared maintenance responsibilities; d) technical and non-technical aid during operational and managerial emergencies; and e) maintenance of levels of trust and engagement between key stakeholders.
- *Complementary commercial activity in parallel to the energy service income is a must*. This allows implementation of survival measures and supports future investments. In Coopeguanacaste this has been achieved, for instance, by selling efficient electrical appliances at low interest rates, wholesaling air time for prepaid mobile phones, and offering high speed internet and digital TV. In Aprodelbo, some agricultural business have been explored. In Boca de Lura, selling cold drinks and providing photocopying services have allowed some income generation.

4.2.2 Barriers: (six sources of obstacles/struggles)

- *There is a general lack of historical information and statistics*. This situation affects mainly the monitoring and evaluation of CRE projects, and therefore ongoing operations and any potential improvements. This was noted in the majority of communities visited in Central America, including Boca de Lura. For instance, not all meetings held are documented, operational logs (if any) are not taken properly, and there is almost nil follow up of conflicts with end-users and stakeholders. Good reporting practices were evident in Coopeguanacaste and Aprodelbo, probably because both are subject to regulation where basic indices must be reported regularly, but most of this data is either not made publicly available, or is published only in the form of basic general annual reports. Thus, evaluators have to guess the working conditions of RE power systems, which may lead to inaccurate conclusions and/or recommendations.
- *Administrative processes from international organisations and donors are sometimes not suitable for CRE*. This has affected access to grants and loans as locals usually struggle with: accessing internet webpages in foreign languages; traveling to cities for collecting the required paper work; finding adequate legal advice; and matching the interests and expectations of outsiders. Aprodelbo reported periods when project financiers only accepted specific projects, e.g. water over electricity, or climate change mitigation over infrastructure. Coopeguanacaste suffers from this lack of appropriate support as well because rural electric coops are considered as private organisations and are sometimes excluded from donations and credits, leading to dependency on intermediaries.
- *There is low level of trust on the part of local leaders towards government*. In Boca de Lura there is a general feeling of neglect by local institutions among members. Also, pressure to hand over the CRE project to private companies was reported by interviewees in Aprodelbo, which may be associated with subtle corruption. Further, community leaders in Coopeguanacaste feel they could not compete with multinational utilities if the regional electricity market, currently working only at transmission level, would be extended to the distribution level as political support tends to reside with the big players.
- *Local supply chains of RE generators and system components are limited*. Although local markets for RETs are increasing in the region, there is still high dependency on external suppliers (from the USA and EU), reducing options for training of local technical staff and exploration of local technological solutions in the region. In Nicaragua, there is a good example of manufacturing of RE generators in a local workshop (ATDER-BL, 2017) which is currently supporting operations in Aprodelbo.
- *SHS programs are perceived as a social commitment and not as a commercial opportunity*. Coopeguanacaste and Aprodelbo have deployed SHS programs (systems between 50-120Wp) to reach extremely isolated households, but only as a subsidised secondary activity. In contrast, community members in Boca de Lura have opted to buy small SHS (<50Wp) with personal funds for lighting and entertainment at home, indicating willingness to pay and the potential for a sustainable business model.
- *Political biases tend to limit rural electrification efforts via community-driven models*. In Panama and Costa Rica there is a traditional preference for national grid extensions for rural electrification, while letting donors implement SHS programs and stand-alone systems (school/clinics) in remote areas. In Nicaragua, off-grid micro grids across the country are enthusiastically promoted. The attitudes of central government towards different electrification models may negatively influence the country statistics on electricity access, as people served with SHS and stand-alone systems are sometimes not included in the national data and could also diminish interest in supporting new CRE projects.

4.2.3 Opportunities: (four ways to increase CRE adoption)

- *There is a huge potential for implementing bioenergy CRE initiatives*. Electricity production from small-scale biomass projects is generally overlooked despite the abundance of natural resources and agricultural activities present in rural areas in Panama, Nicaragua and Costa Rica. For instance, biomass generators and/or gasifiers could be fuelled using agricultural bio-waste from nearby farms or from other sources. For instance, Coopeguanacaste is exploring the adoption of a new power plant of 5 MW using municipal waste from neighbouring communities.
- *Exploit modern rural electrification technologies*. Pilot stand-alone systems (e.g. in schools or clinics) could later be upgraded into minigrids to increase access levels and support domestic and productive uses, as suggested for Boca de Lura (Madriz-Vargas, *et al.*, 2017b). Where appropriate, minigrids already in operation could be connected to existing minigrids in nearby villages or to the central grid to increase redundancy and reliability of the networks (Pokhrel, *et al.*, 2013), as implemented in Aprodelbo. In both cases, original RE generators can be reused in new configurations and even configured in hybrid modes, e.g. PV-hydro, or PV-wind-hydro. Currently, there are commercial repowering and automation solutions to convert old systems into new ones with sophisticated control features that offer high efficiency and reliability. Implementation of new modern minigrids can serve areas neglected by utilities, as generally observed in Nicaragua.
- *Exploit the energy nexus with other sectors*. Most current projects are perceived as electricity only, but multi-sector goals in new initiatives must be encouraged as a means of capturing funds to sustain current project needs and attracting new investment for capacity development, engagement activities, and promote productive uses. Beyond the typical energy-water connection for education or health, CRE projects may also create conditions for (Ley, 2017, TERI, 2016): a) women's empowerment, b) securing food supply, and c) enhancing resilience to climate change. These nexus could be part of the rationale for new proposals and local policy arrangements.
- *Policy could be implemented to support new CRE initiatives*. In particular for: fulfilling CRE general needs (**Section 4.2.1**); helping current CRE projects to overcome common struggles (**Section 4.2.2**); and encouraging new CRE endeavours by creating policy instruments that support them, and regulation to prevent unfair competition from private or public sectors.

See a summary of the common needs, barriers and opportunities in **Figure 4**.

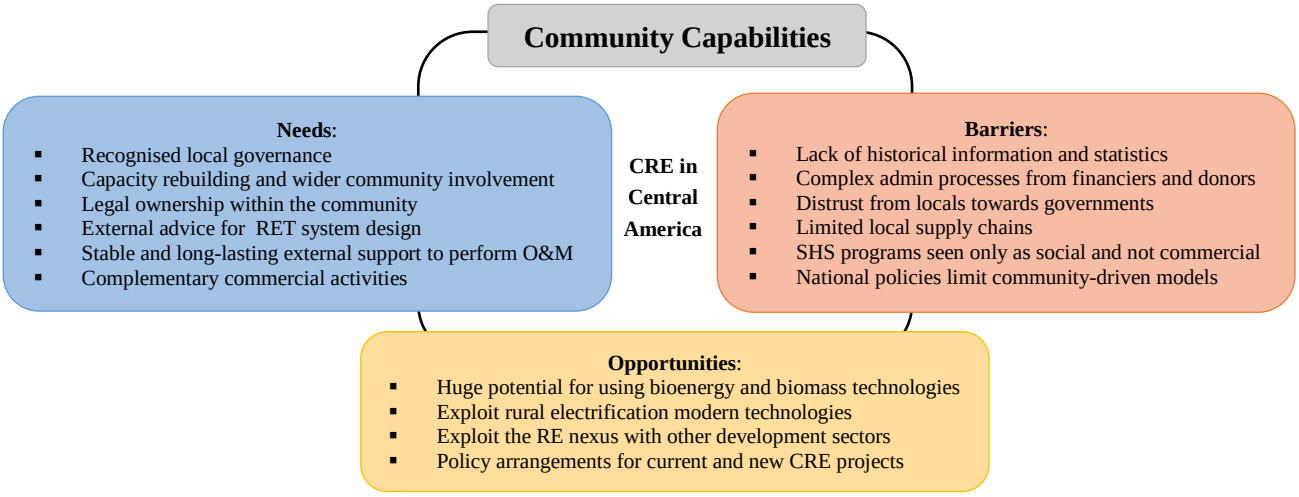

Figure 4. Summary of needs, barriers and opportunities for CRE in Central America

5. Final remarks

This comparative study has set out the main findings after an extensive field investigation on rural electrification projects involving community-based models in three Central American countries. The selected community renewable energy (CRE) projects have been recognised nationally and internationally as positive experiences leading to rural socio-economic development and energy poverty alleviation in the Boca de Lura community (Boca de Lura, Panama), in the San Jose del Bocay town (Aprodelbo, Nicaragua), and in several communities located in the Nicoya Peninsula (Coopeguanacaste, Costa Rica).

In general, a basic level of community capability across the major activities in CRE projects seems to be the major factor influencing success within the case studies. In addition, the main needs and barriers relate more to legal, organisational, and political aspects than to social, technical or environmental ones. Therefore, suitable interventions and policy arrangements to cover current needs and overcome present struggles would seem to be critical to ensure operational sustainability of these CRE projects.

Some opportunities point to more strategic project planning and renewable energy system design using newly available rural electrification technologies and creation of adequate policy instruments. In particular, project planning should aim to capture complementary budgets for:

1. social engagement activities after commissioning
2. access further training for capacity rebuilding on a yearly basis, and
3. expand the capacity installed in RE power plants to meet non-residential demand.

Although the common needs, barriers and opportunities discussed are specific to the Central American region, some general lessons learnt are:

- Implementation of a strict 100% community-based energy venture, that is completely owned, managed, operated and maintained by locals, is not practical.
- Having a local social structure legally acknowledged is critical for gaining credibility and bankability to access funds from private or public sources.
- A combination of rural electrification models is the most effective way to increase electricity access levels, e.g. minigrids plus SHS programs in the same village, or grid extension plus stand-alone systems in the same concession area, etc.
- Permanent presence of a local champion (or supportive external organisation) is vital for continuous training of local technicians and community capacity development.
- A closer look at political realities around CRE is fundamental to unlock potentialities regarding the energy nexus with other rural development sectors.

It is expected that findings from this cross-case study will assist debates on policy making by providing evidence-based insights from successful CRE projects, promoting knowledge exchange across developing regions, and creating bridges between energy access experts, community activists, and industry stakeholders for future research and successful deployment of CRE in: Latin America and the Caribbean; the sub-Saharan Africa; the Middle East; and the Asia-Pacific.

References

ATDER-BL, 2017. 'Project History-Aprodelbo', [Online]. Association of Rural Development Workers - Benjamin Linder. Available: http://www.atder-bl.org/Projects.html [Accessed 29-01 2017].

Bhattacharyya, S.C. and Palit, D. 2014. 'Mini-grids for rural electrification of developing countries: analysis and case studies from South Asia', Switzerland, Springer International

Bomberg, E. and McEwen, N., 2012, 'Mobilizing community energy', *Energy Policy*, 51, p435-444.

Canessa, R., Santome, J.M. and Buss, I.N., 2014, 'EURO-SOLAR program ex post evaluation ', ICD-ALA European Program for Latin America, SACO Consortium (SAFEGE-COWI).

Franz, M., Peterschmidt, N., Rohrer, M. and Kondev, B., 2014, 'Mini-grid Policy Toolkit - Policy and Business Frameworks for Successful Mini-Grid Roll-outs', RECP. Eschborn, Germany.

Ley, D. 2017. 'Sustainable Development, Climate Change, and Renewable Energy in Rural Central America'. In: Uitto, J.I., Puri, J. and Berg, R.D.v.d. (ed.) Evaluating Climate Change Action for Sustainable Development. Springer International Publishing.

Madriz-Vargas, R., Bruce, A. and Watt, M., 2015, 'A review of factors influencing the success of community renewable energy in developing countries', Proceedings Asia-Pacific Solar Research Conference, Brisbane, Australia, 8-10 Dec

Madriz-Vargas, R., Bruce, A. and Watt, M., 2017a, 'Community Renewable Energy in Nicaragua: Sustainability Assessment of "APRODELBO".', Solar Energy Lab, Universidad Nacional. Heredia, Costa Rica [Original in Spanish].

Madriz-Vargas, R., Bruce, A., Watt, M., Mogollón, L.G. and Álvarez, H.R., 2017b, 'Community renewable energy in Panama: a sustainability assessment of the "Boca de Lura" PV-Wind-Battery hybrid power system', *Renew. Energy Environ. Sustain.*, 2, p1-7.

Madriz-Vargas, R., Bruce, A., Watt, M. and Rojas, Y.A., 2016, 'Energy with Development: 50-years Experience of Community-driven Rural Electrification and Future Challenges for COOPEGUANACASTE in Costa Rica', Proceedings Asia-Pacific Solar Research Conference, Canberra, Australia, 28 Nov to 1 Dec.

OECD/IEA, 2016, 'World Energy Outlook', International Energy Agency. Paris.

Paleta, R., Pina, A. and Silva, C., 2012, 'Remote Autonomous Energy Systems Project: Towards sustainability in developing countries', *Energy*, 48, p431-439.

Pokhrel, S., S.K.Singal and Singh, S.N., 2013, 'Comprenhensive Study of Community Managed Mini Grid', *International Journal of Emerging Technology and Advanced Engineering*, 3, p514-520.

Rae, C. and Bradley, F., 2012, 'Energy autonomy in sustainable communities—A review of key issues', *Renewable and Sustainable Energy Reviews*, 16, p6497-6506.

REN21, 2017, 'Renewables 2017 Global Status Report', Renewable Energy Policy Network for the 21st Century. Paris: REN21 Secretariat.

Seyfang, G., Park, J.J. and Smith, A., 2013, 'A thousand flowers blooming? An examination of community energy in the UK', *Energy Policy*, 61, p977-989.

Smillie, I. 2000. 'Mastering the machine revisited: poverty, aid and technology', Intermediate Technology.

Sovacool, B.K. 2014. 'Defining, Measuring, and Tackling Energy Poverty'. In: Halff, A., Sovacool, B.K. and Rozhon, J. (ed.) Energy Poverty. Global Challenges and Local Solutions. UK: Oxford University Press.

TERI, 2016, 'Exploring Factors that Enhance and restrict Women's Empowerment through Electrification', The Energy and Resources Institute (TERI). New Delhi, India.

Terrapon-Pfaff, J., Dienst, C., Konig, J. and Ortiz, W., 2014, 'How effective are small-scale energy interventions in developing countries? Results from a post-evaluation on project-level', *Appl. Energy*, 135, p809-814.

Walker, G., 2008, 'What are the barriers and incentives for community-owned means of energy production and use?', *Energy Policy*, 36, p4401-4405.

Walker, G. and Devine-Wright, P., 2008, 'Community renewable energy: What should it mean?', *Energy Policy*, 36, p497-500.

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