Community Energy Planning in the Alexander Skutch Biological Corridor

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Abstract

The purpose of this major paper is to explore the possibility of developing a community energy project in rural Costa Rica. Two case communities were selected in the Alexander Skutch Biological Corridor: Santa Elena and Quizarra. The paper assessed the current energy policy framework in Costa Rica, and determined whether community energy planning could be a viable option for the communities. An energy assessment of the communities was performed through qualitative and quantitative research methods. Various energy actors in Costa Rica were also interviewed in determining the future of distributed energy generation in the country. The paper used RETScreen as a tool to analyze the financial viability of a solar PV project in the communities. Following the policy and financial assessment, the paper identified the following barriers to the success of community energy in the ASCBC as: the lack of a supporting Feed in Tariff (FIT) policy and incentives for renewable energy development in the country, financial barriers such as limited access to funding and high interest rates on loans, and a lack of institutional support. The paper provides recommendations for advancing community energy in Cost Rica, and alternative methods for lowering electricity consumption, such as energy efficiency and demand management strategies. The paper contributes to an understanding of the energy policy framework in Costa Rica, and the role that distributed energy generation can play. It also provides insight into energy usage and the needs of the ASCBC communities, and highlights the importance of energy education and community engagement.

Foreword

This Major Research Paper (MRP) focused on climate change & energy policy, renewable energy, sustainable business models & community energy planning. The area of concentration for my program is “Community energy planning in rural Costa Rica”, aimed at investigating possible community energy models that could be applied in Costa Rica. This MRP has enabled me to understand what factors are needed to make community energy a reality, and to understand alternative, non-conventional energy systems that can be applied in Costa Rica. I was also able to understand the impacts of climate change on the energy sector in the country, and recognize the influence that community energy can have on the social, economical and ecological segments of a community.

The importance of energy sustainability was made apparent to me during a trip to Jamaica, where I was enlightened to the country’s extremely high-energy prices and use of diesel as a source of electricity. This realization led me to York University’s MES program, where I have been able to research the ways in which policies can stimulate innovation and increase accessibility to renewable energy resources in regions where it may abundant, but not yet adopted. The courses I have taken, and the number of experiences during my program, have provided me with valuable knowledge and perspectives on sustainable energy systems. These experiences included an internship with Nordisk Folkecenter in Denmark, field research in Costa Rica, participation in The World Energy Engineering Congress in Orlando, Florida, and participation in the Ontario Climate Consortium Conference. Working with these organizations has allowed me to understand the importance that my research can have on policymaking.

The views expressed in this paper are the author’s alone and may not be reflect those of the above-mentioned or York University.

ERRATA:

Figure 5.7: Solar array on figure reads 1.5 kW per household, should read 1.2 kW

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Acronyms

AyA	Institute of Aqueducts and Sewers
AED	Association for Energy Development
ARESEP	Public Service Regulating Authority
AARC	Ad Astra Rocket Company
ASADAS	Association of Aquatics and Sewage Management (Associaciones Adminstradoras de Sistemas de Acueductos y Alcantarillados Sanitarios)
ASBC	Alexander Skutch Biological Corridor
BOT	Build Operate Transfer
CC	Costa Rican Colons
CG	Centralized Generation
CE	Community Energy
CEED	Centre for Environment and Energy Development
CNFL	Compañía Nacional de Fuerza y Luz
CPSU	The Urban Sustainability Center- Centro Para La Sostenibilidad Urbana
DG	Distributed energy Generation
ESPH	Empresa de Servicios Públicos de Heredia
FIT	Feed In Tariff
GW	Gigawatt
Ha	Hectare
ICE	Costa Rican Institute for Electricity (Instituto Costarricense de Electricidad)
IEC	National Institute of Statistics and Census
INPA	National Institute for Research in the Amazon
JASEC	Junta Administrativa del Servicio Eléctrico de Cartago
KM	Kilometer
KW	Kilowatt
KWH	Kilowatt Hour
LDC	Local Distribution Company
MINEA	Ministry of Energy and Environment
MW	Megawatt
MWH	Megawatt Hour
PV	Photovoltaic
RE	Renewable Energy
SIN	National Interconnected System
SIEPAC	Central American Electrical Interconnection System
SES Lab	Laboratorio de Sistemas Electronicos para la Sostenibilidad
TEC	Technological University of Cost Rica
USD	United States Dollar
Wp	Watt power

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1. Introduction

The 21st century has brought a massive transformation to the energy sector's technological and institutional components. The ownership and the location of energy systems have not been challenged until recently, with the emergence of community energy projects. Traditionally, society's relationship to energy generation has been one that is unfamiliar, distant, and uninvolved in the process of production and distribution of energy. For many years energy has been managed, owned and operated by institutions that have limited the role of community involvement. However, as communities become more aware of the impacts of *business as usual* scenarios for the energy industry, traditional models become challenged due to their often-negative impacts on the social and ecological environment. Historically, energy systems have operated in large, distant, centralized generation (CG) systems. Their reliability and sustainability is now being challenged as the realities of climate change become more apparent. Climate change will continue to impact energy reliability, security and efficiency, and traditional models are more susceptible to these impacts. In some cases, the impacts of climate change may lead to energy poverty. As a method of adapting to these realities, alternative models of energy systems must be explored.

Distributed energy generation (DG) systems offer new models for climate change mitigation in the energy sector. Due to the complexity of energy systems, and the various legislative protocols involved, there is a general definition as of what distributed energy truly means. Currently, the National Renewable Energy Laboratory defines DG resources as, "a variety of small modular electricity-generating or storage technologies that are located close to the load they serve" (Friedman, 2002, p.1). The key element here is *location*. Energy systems that are positioned close to the load can be characterized as decentralized energy systems. DG systems are smaller and easier to manage, and therefore operate more efficiently and are flexible and easier to deploy (FCPC, 2013, p.6). They also tend to rely on cleaner and less risky energy sources. This is a shift away from large centralized systems that serve mass populations over great distances, but which are not as efficient and easily deployable. DG systems typically use renewable energy sources such as, wind, solar, biomass, biogas and small hydro (FCPC, 2013). DG can take various ownership models. However, Community Energy (CE) models have been identified as encouraging a more cooperative, multi-actor, and bottom-up distributed model approach *(Ibid)*. CE can provide communities with decentralized sources of energy and can help build positive momentum towards harvesting clean energy and local engagement.

Centralized systems have been common practice in most countries, Costa Rica included. However, DG is slowly being recognized as a positive alternative to classical models of energy generation (Bouffard, Krischen, 2008, p.4504). Costa Rica has a long-standing tradition of being an environmental leader in conservation and protected areas; 25 per cent of its national territory is protected as National Parks (Government of Costa Rica, 2015). It also has one of the highest electrification rates in Latin America. In 2010, Instituto Costarricense de Electricidad (ICE- Costa Rican Institute for Electricity Group) reported 99.11% electrification across the country (OLADE & UNIDO, 2011, p.14). Moreover, The Happy Planet Index rated Costa Rica as the happiest country in the world (2015).

This extremely green portfolio, and almost 100% electrification rate, has been accomplished without the use of DG and CE models. The country has relied on the use of traditional energy models of large, monopolized hydropower grid based systems.

By completing a policy analysis and sustainability assessment, this paper argues that CE is a sustainable option for developing new energy systems in Costa Rica. Although CE could benefit the social and environmental climate of communities in Costa Rica, the current framework does not create an environment where CE can exist, and where communities can maximize the benefits of community led energy projects.

1.1 Methodology and Outline

This paper will explore the applicability of CE in Costa Rica through a policy analysis and financial viability. Two communities in the Alexander Skutch Biological Corridor (ASBC) were assessed for this study: Santa Elena and Quizarra.

The questions guiding this study were:

- Can a community energy model work in rural Costa Rica, while staying within its policy framework?
- Is it viable for the communities of the ASBC to develop a solar PV community energy project?

The paper will explore the importance of community energy in Costa Rica, and determine if it is a viable option for the ASBC communities. This study has identified community energy as an alternative to Costa Rica's current monopolistic approach to energy development, as well, as a tool to address local economic, social and environmental concerns. The elements required to research this topic include an assessment of Costa Rica's energy policy framework, an understanding of community energy models that have achieved global success, the case communities' energy profiles and needs assessment, and a business analysis of a community energy project for these communities.

The study will employ a variety of research methodologies including: theoretical research, a review of best practices for rural electrification planning; and descriptive qualitative and quantitative interviews and questionnaires with community members in the two communities. Interviews with key energy actors were also conducted in Costa Rica. In preparation for this research, field visits were made to several community energy projects in Denmark. Wind, solar, and biogas projects were observed. Field visits to various renewable energy sites were also made in Costa Rica, in order to better understand electricity generation in the country.

The paper will start by exploring the impacts of climate change on the energy needs of Costa Ricans, and the role of DG alongside CE in limiting these impacts. Following this, the paper will attempt to define CE and explore the Danish concept of it. Chapter 2 analyzes the energy industry in Costa Rica and the legislation that frames it. Chapter 3 describes the chosen communities in the ASBC. Chapter 4 outlines data results from within the communities. After establishing the current policy framework, and an evaluative framework, an assessment of CE in the ASBC is undertaken. This will determine whether or not Costa Rica's current policy framework supports CE as an ownership model for RE systems. Chapter 5 will also explore the various models of CE that could work in Costa Rica while staying within its current policy framework. Lastly, chapter 6 provides recommendations and next steps to follow for the adaptation of CE in Costa Rica.

1.2 Impacts of climate change on energy needs in CR

Costa Rica presents a very unique case for renewable energy research, as the country has a global reputation for its high renewable energy portfolio. In 2015 Costa Rica generated 100 percent of its electricity from renewable sources for 75 consecutive days (ICE, 2015, p.3). A majority of this energy was generated from hydropower, with a small portion coming from wind and geothermal technologies. With 80 percent of Costa Rica's electricity being sourced from hydro, the potential impact of climate change poses a threat to energy generation in the country.

The 2007 IPCC report on Climate Change indicates that by mid-century Latin America will experience changes in precipitation patterns, and the disappearance of glaciers. This will have a significant effect on water availability for human consumption, agriculture and energy generation (119). Costa Rica relies on the availability of abundant water resources to supply its hydropower generation grid. As the effects of climate change become more pronounced in Costa Rica, it will ultimately lead to a significant reduction in water flow for hydro production. This will impact revenue streams, ultimately leading towards the need for alternative sources of power. A climate change scenario study projected a reduction of 43% in Costa Rica's hydropower production, ultimately leading to an equivalent loss in revenue for the sector (Murieta and Chiabai, 2013, p.20). Already as a result of unpredictable weather patterns, electricity prices have doubled since 2007 due to variable hydroelectric output, causing an increased use of thermal power (bunker fuel), and increased operating costs (World Bank, 2015, p. xi).

As climate change impacts weather patterns, the frequency of El Niño events is also expected to increase considerably. El Niño events are known to cause peculiar formations in weather patterns, resulting in extreme flooding in some areas, and severe droughts in others

(Wenju, Borlace, Lengaigne, Rensch, Collins, Vecchi, Timmermann, Santoso, McPhaden, Wu, England, Wang Guilyardi & Jin, 2014, p.111). For Costa Rica the frequency of extreme El Niño events could impact the reliability of hydropower production. Unpredictable weather patterns could also impact the reliability and durability of the power transmission lines that carry power for long distances, as is the case in Costa Rica (Weigl, 2014, p.23).

Many of Costa Rica's hydropower generation sites are large-scale projects, requiring large transmission lines for distributing power to the grid. In addition, large-scale hydro projects have negative social and environmental impacts and can even contribute to the release of methane into the atmosphere (Fearnside, 2007). Costa Rica operates with both run of the river facilities and dams with reservoirs. Both types have the potential to be disruptive to the ecological wellbeing of the rivers on which they are situated.

Large-scale hydropower generation can have direct and indirect social and environmental consequences, such as: water diversions, disruption of aquatic species, the relocation of people, as well as a boom and bust effect on the local economy (IPCC, 1996, p.41). However, hydropower generation is preferred in Costa Rica due to the country's unique allocation of natural resources. The negative impacts of it go unnoticed. Dr. Philip Fearnside; a research scientist at the National Institute for Research in the Amazon (INPA), has found that hydroelectric dams are emitters of GHG's; specifically in the form of carbon dioxide and methane (2007). Dams can create circumstances for methane gases to be produced and released into the atmosphere. According to Dr. Fearnside, organic matter that is buried during the construction of a reservoir decomposes in the oxygen-poor water near the bottom of the reservoir (2007). The lack of oxygen decomposes the matter, releasing methane into the atmosphere *(Ibid)*. Research on methane released from hydropower dams has not been conducted in Costa Rica.

However Dr. Fernside's research is focused in Brazil, which has a similar geography and energy market to that of Costa Rica.

As the impacts of climate change effect water availability, hydropower generation will be impacted. Costa Rica already substitutes thermal power for hydro during times when hydropower cannot meet peak demand. The Thermal Power Source is "imported diesel and bunker fuel" (Sutch, 2011, p.41). Thermal generators are also used during times of El Niño weather patterns, where Costa Rica experiences a dry season, with extreme droughts and decreased rain fall (Sarouhan, 2015).

Approximately 98% of Costa Rica's electricity system is state owned and powered through large hydropower projects (OLADE & UNIDO, 2011, p.22). DG is not common in Costa Rica, and no community energy models currently exist. The current energy generation system is situated around large, centralized systems that are located far from the consumers, and are owned by large institutions. Introducing alternative energy sources and models could help the country to make a shift from the use of fossil fuels during shortfalls of hydroelectric generation, and shift towards an energy grid that benefits from the distributed generation model.

1.3 Importance of DG in CR

From 2002 to 2014, the population of Costa Rica grew by 14 per cent. Its GDP per capita doubled in the same period, (see figure 1.1 World Bank, 2015). An increasing population in parallel with an increasing GDP impacts energy consumption patterns. As the two factors grow, there is likely to be increased energy consumption in the country (see figure 1.2). Between 2002 and 2014, energy consumption in Costa Rica increased by 42 per cent (US Department of Energy, 2016). There is a direct correlation between these indicators, requiring not only increased installed capacity, but also the need to look into energy efficiency, and to demand response strategies for the country.

Current energy policies in Costa Rica lack effective energy efficiency programs and demand response strategies. Its National Energy Plan does relay the importance of energy efficiency programs for the country, but fails to provide long term methods on achieving energy efficiency in the residential sector. The National Energy Plan blames the country's ineffectiveness in energy efficiency programs on the lack of resources and institutions within its Ministry of Environment and Energy (MINAE, 2014, p.19). A study done by the Economic Commission for Latin America found that countries in Latin America have developed legal frameworks to regulate and incentivize energy efficiency over the years (Guzman, 2015). However, problems still remain, due to a lack of continued government funding for programs, a lack of continuity of energy efficiency programs and difficulties in monitoring the success of these programs *(Ibid).* These issues have also been identified as barriers to the success of energy efficiency programs by the Ministry of Environment and Energy in its National Energy Plan[1].

Demand response strategies such as time-based rates or other financial incentives are not presently utilized in Costa Rica. Currently, only one LDC (local distribution company) out of eight has a time-based rate program for electricity consumption. CNFL, which services the central core of the country, offers its customers hourly rates dependent on time of day and usage (MINAE, 2014, p.31). However, this program is voluntary and is not advertised to the public. As a result of this, it has not gained much public acceptance or acknowledgement *(Ibid).*

[1] In the National Energy Plan MINAE indicated that there is a lack of institutions and resources for energy efficiency programs in the country (MIANAE, 2014, p19-21).

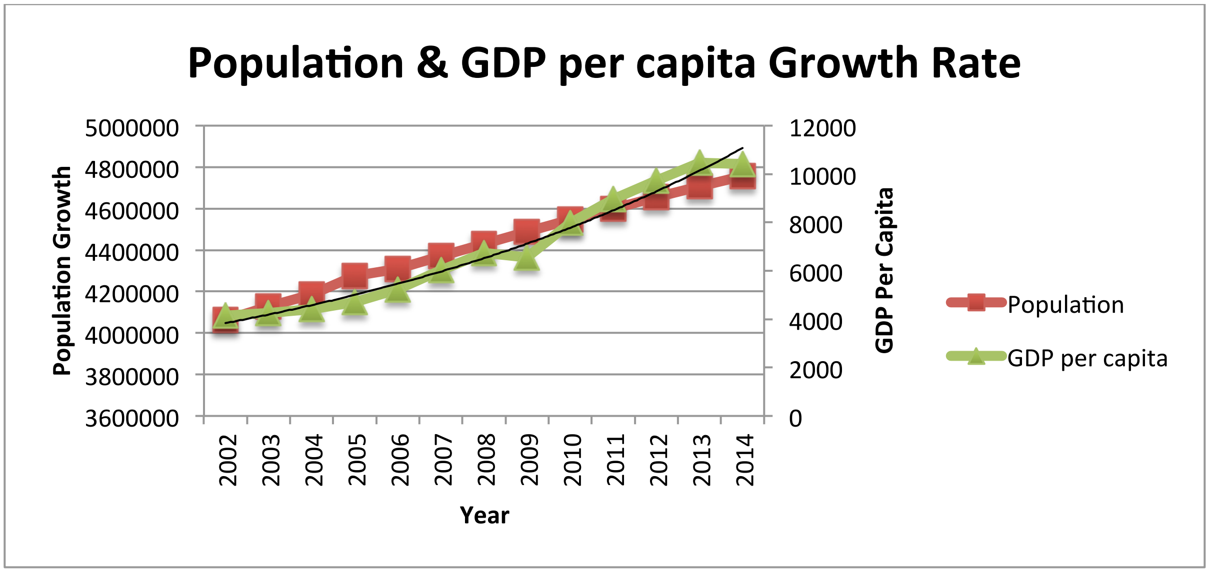


Figure 1.1: Historical development of GDP per capita growth and population growth trend. Source of Raw Data: World Bank, 2015. [Graphical representation done by author]

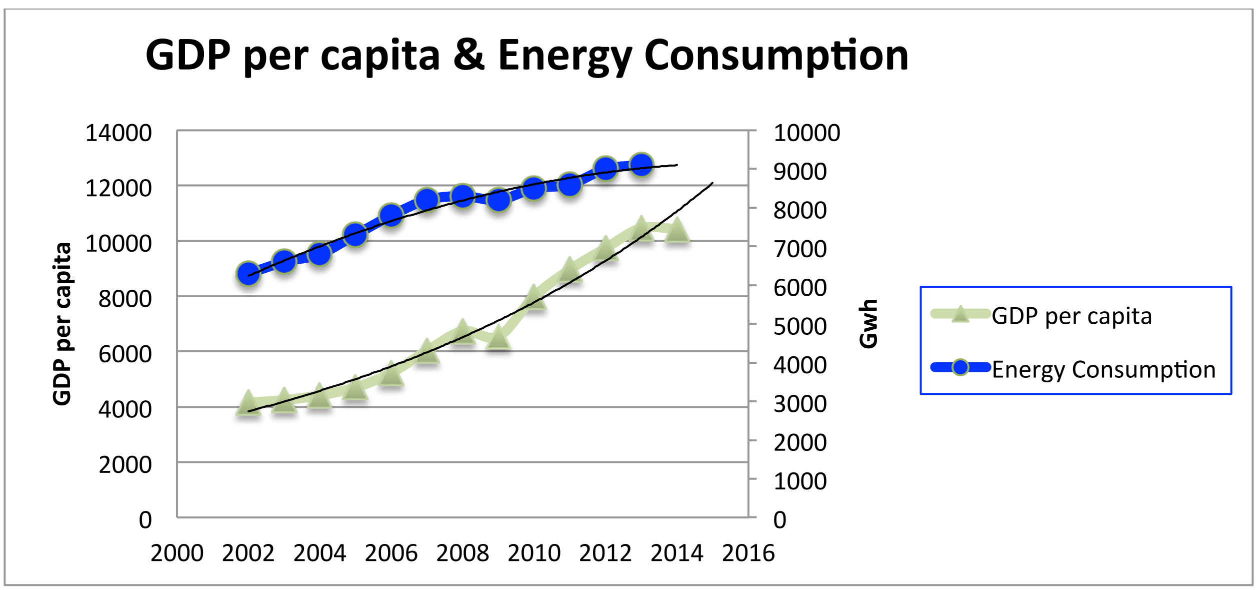


Figure 1.2: Historical and future projections of GDP growth and energy consumption in Costa Rica. Source of Raw Data: Reegle 2015. [Graphical representation done by author]

In 2014, Costa Rica had an installed generating capacity of 2.8 GW, with a net generation of 10.TWh (CEPAL, 2015, p.24). To meet annual increases, Costa Rica will have to increase more than 1 GW in its installed capacity by 2021, going from 2.8 GW in 2014, to 3.9 GW in 2021 (Reegle, 2015). This would require the country to install approximately 27 MW annually for the next seven years to reach its goal. Community energy can act as a tool in meeting these targets, and potentially lowering the projected installed capacity requirement. It could provide education on energy generation and consumption, impacting energy efficiency behaviors, and can stimulate demand response strategies.

Despite the increase in GDP, 22 per cent of the country's population still lives below the poverty line (World Bank, 2015). Rural communities are at the forefront of these figures; experiencing slow and low economic growth, while adjacent urban centers attract economic advancement, leaving the peripheries with little resources (Khan, 2001). Distributed energy projects could play a positive role in providing better and sustainable livelihoods for these communities through reliable, accessible, and resilient energy sources (Walker, 2008, p.4401). The impact could be greater if DG follows a community-based model *(Ibid)*. Community-based energy projects have been shown to redistribute "economic regeneration, social cohesion and public understanding and support for renewable energy" *(Ibid)*. Community-based energy projects would help in build self-sufficient, resilient and energy independent communities, while diversifying Costa Rica's energy mix and minimizing the use of fossil fuels.

Santa Elena and Quizarra have been chosen as the focus areas for a number of different reasons. Historically, these communities have faced the development of a hydroelectric dam in the Rios Pinas Blancas (The White River), a river that connects the several communities in the ASBC. Conducting research to determine if a community energy project could be feasible in these two communities, would not only contribute to providing energy independence and climate change resiliency, but would also provide the communities with tools to develop their own energy sources, in addition to strengthening their position in the opposition to the hydro dam. The communities opposed the development of the dam because it would have had a negative impact on their livelihoods and their use of the river, in addition to the degradation it would have caused to the surrounding environment (Respondents, personal communication, February 3th 2016).

Secondly, the ASBC has a unique relationship with York University. It is a part of the Las Nubes Project, which is steered by the Faculty of Environmental Studies. Las Nubes: meaning "*in the clouds",* is a rainforest which was generously donated by Woody Fisher, a prominent researcher in Toronto. The rainforest surrounds the communities of the ASBC (FES, 2016). The communities within the corridor have had a close relationship with the university due to their proximity to the rainforest. The mission of the Las Nubes project is to provide expertise on environmental conservation through student research, environmental education and community engagement initiatives. No research on energy planning has been undertaken in the communities of the ASBC until now. It is a very important area of research that could be extremely valuable to them. This research paper will support the mission of the Las Nubes Project by researching methods of ensuring community well-being and conservation.

It is important to consider distributed energy generation in Costa Rica, as centralized systems face issues around transmission, distribution, infrastructure costs, inefficiencies in transmission power loss, grid instability and reliability, as well as negative environmental and social impacts (Martin, 2009). They operate with a top down approach, empowering only those at the institution level. Whereas distributed energy systems are built at the community level, through a bottom up approach, keeping the needs of the community in mind. Distributed energy systems do not require imported resources from non-local sources and the building of lengthy transmission lines (Bouffard et al., 2008, p.4505). Community energy has the potential to simultaneously address social, economic and environmental issues, while accelerating the green energy market.

A community energy model would allow for new players to enter the energy market. Currently, Costa Rica's energy market is monopolized by ICE, a state owned and operated entity that controls 100 % of the transmission system, and a large part of the generation and distribution of electricity in the country. The current transmission grid is extremely lengthy, reaching from the north end of the country bordering on Nicaragua, and stretching south to Panama, running a total of 1913 km, (see figure 1.3, Weigl, 2014). The distribution grid runs impressive distances with 21,000 km of power lines that are operated by two public service companies and six electricity cooperatives (Weigl, 2014, p.24). See table 1.1 for distribution of each local distribution company's (LDC) territory. Power lines running from centralized energy out such long distances carry a real risk of power losses.

Figure 1.3: SIEPAC grid layout of Costa Rica (Weigl, 2014, p.24).

<u>Energy distribution in Costa Rica</u>

Local Distribution Company	Clients (%)	Sales (%)	Territory serviced (%)
ICE	43	39	77.5
CNFL	34.21	39	1.9
JASEC	5.68	5.65	2.4
ESPH	4.66	5.80	0.2
COOPELESCA	4.95	3.99	9.2
COOPEGUANACASTE	4.38	4.07	6.2
COOPESANTOS	2.52	1.39	2.2
COOPALFARO	0.55	0.26	0.4

Table 1.1: Distribution of Energy in Costa Rica, % of clients, % of Sales and % of Territory each local distribution company has (Meza, 2015).

The top two LDC's, ICE and CNFL, hold 80% of the distribution market in the country. These LDC's are state owned and operated, leaving little room for other players to enter the electricity market. Development of DG would help alleviate some of the political and social dilemmas that flow from the current model. Considering Costa Rica's close location to the equator, the country receives an abundance of solar irradiance, (see figure 1.4), yet solar powered systems supply less than 1% of the country's energy mix (Cepal, 2015, p. 24).

This paper will focus on solar PV as an energy source for distributed energy systems. Distributed energy systems can also be deployed through the use of micro hydro, wind, biogas, biomass and geothermal energy. However, as the study progressed, biogas was identified as a more suitable alternative energy solution for the communities. The communities have access to a lot of agricultural waste, making biogas an appealing option. Biogas could be used for electricity generation or solely for cooking gas. During the study, the author did come across two self-made biogas application systems constructed by community members. However, installations were not active due to complications with the materials used to make them. Biogas was not assessed further, as its application in the communities goes beyond the scope of this paper. This paper will only focus on solar PV technology in community energy planning.

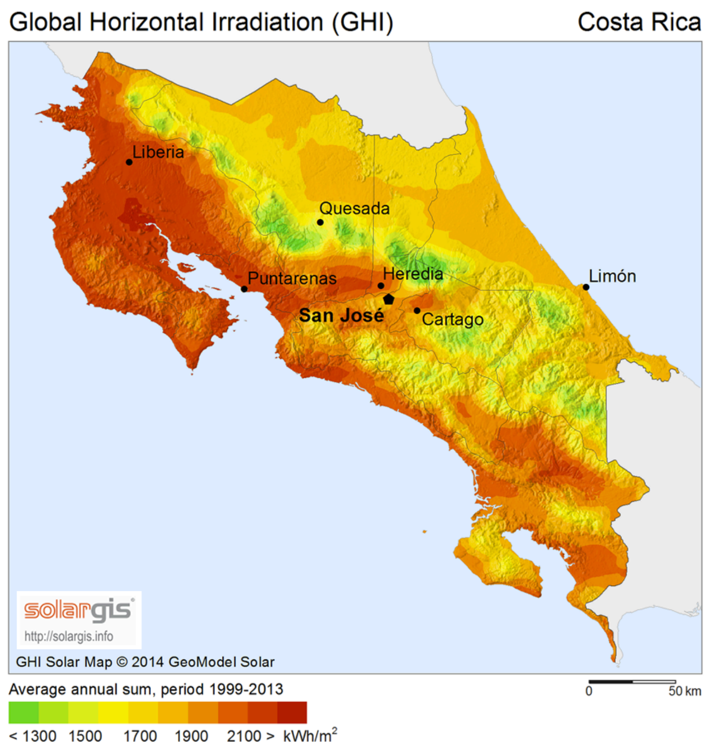


Figure 1:4: Solar irradiance of Costa Rica (Solar GIS).

Due to the different political, economic and social contexts, a model for CE that has worked in one country may not be replicable in another. However, the potential for success or barriers can be identified through modeling CE in other environments. Eric Viardot (2013) supports the model of cooperatives at the community level for renewable energy projects. Energy cooperatives that are community based create opportunities for secure investments, and remove concerns about external investor interests. At the same time they enable people to make changes within their own homes and lifestyles (Viardot, 2013, p.761). Many studies in the U.S have also shown, that successful renewable energy projects are typically managed by cooperative ventures, as opposed to conventional corporations (Subbarao & Lloyd, 2011). The success of renewable energy in Germany and the U.K. can be correlated with the rise of cooperative ownership (Walker, 2008, p.4403). Developing a community energy network in Costa Rica would provide local communities with tools to engage with local members, provide access to resources, increase energy literacy, and address other social, economic and ecological concerns.

1.4 CE in CR- Danish concept of CE

The global community has frequently looked to Europe for its low carbon economic models, and recognized the region as a leader in distributed energy generation and community energy projects. Denmark began its community energy journey in the 70's, where communities made concerted efforts to invest into emerging wind energy projects (Client Earth, 2014, p.6). In 2013, 70-80 per cent of wind turbines in the country were co-owned by local groups (Kingsley, 2012).

Denmark was identified as the ideal state for this study, as it has been globally recognized for its leadership role in the development of community energy projects. This study was extended by conducting primary research and data collection at Nordic Folkcenter for Renewable Energy in Denmark and the case communities in Costa Rica. The author reviewed various community owned energy projects and examined which methods could be deployed in Costa Rica with the help of Folkecenter.

In the 1980's, Folkcenter was involved with one of the first community energy projects in the world. Although the concept of community energy has changed since then, its foundation still remains intact; community owned projects that create profit for a common good, not just private interests. The idea was to investigate several different community projects, and to understand the historical and cultural origins of community energy in Denmark, then determine their transferability to Costa Rica.

Ideally, the community energy movement in Denmark would like to use a model where communities have the opportunity to own 80 per cent of an energy project built in their community, with the remaining 20 per cent for private investment (Kruze, 2016). This model would use the profits that the energy system generates to fund common good projects for the community, (see figure 1.5). However, even in Denmark, there are wind projects that have faced local opposition, due to a lack of community consultation and shortfalls in benefits to the local communities *(Ibid).* Often communities are only offered 20 per cent of the shares, while large private investors own 80 per cent or more, leaving little room for community energy to be realized (*Ibid)*. Regardless of the portion of shares the community has access to, the Danish model can only be applied if there is a feed-in-tariff (FIT) policy in place, which is not the case in Costa Rica. Therefore, an alternative model will have to be explored using the current policy framework in Costa Rica.

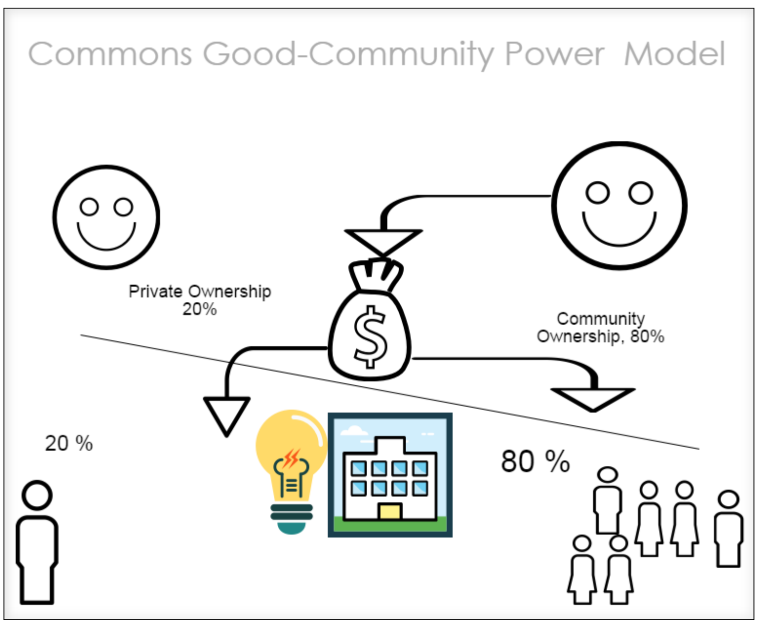


Figure 1.5: Ideal Commons Good Community Power Model for Denmark [Picture designed by author].

Even if Costa Rica decides to diversify its energy mix through the introduction of other renewable energy sources, the development of these energy projects may face local opposition if the traditional, monopoly based model is followed. This was the case in England and Denmark, where opposition emerged due to the fact that an external company or an individual proposed a project that the local population would not benefit from (Loring, 2007). An Australian study found that when communities financially benefit, the acceptance of a project is likely (Gross, 2007, p.2733). This was the case in Denmark, where local communities support went from Not In My Back Yard (NIMBY) to Please On Our Land (POOL) (Kruze, 2016). This study explores the diversification of Costa Rica's energy mix through a community energy approach.

2. Energy in Costa Rica

Hydropower has always dominated the electricity market in Costa Rica (see appendix 1). In 2014 hydropower contributed to 67 per cent of generated electricity. The country's natural geography provides it with substantial volcanic geothermal activity, which accounted for 15 per cent of energy generation, while fossil fuel generation accounted for 11 per cent. Although thermal generation sits at 21 per cent of installed capacity, generation remained relatively low. It could be being offset by geothermal generation. Considering Costa Rica's close proximity to the equator, the country has a natural abundance of solar energy. However, it fails to capture it. Solar generation is so low that it does not even compete on the national energy market. In 2014, total installed capacity was 2.8848 MW and net generation was 10.1 TWH, this is shown in figure 2.1 (Cepal, 2015, p.24). At this time solar energy represented total installed capacity of 1.0 MW, and a generation capacity of 1.5 GWh *(Ibid)*. This is almost entirely made up by the Solar Miravallas park that is owned and operated by ICE.

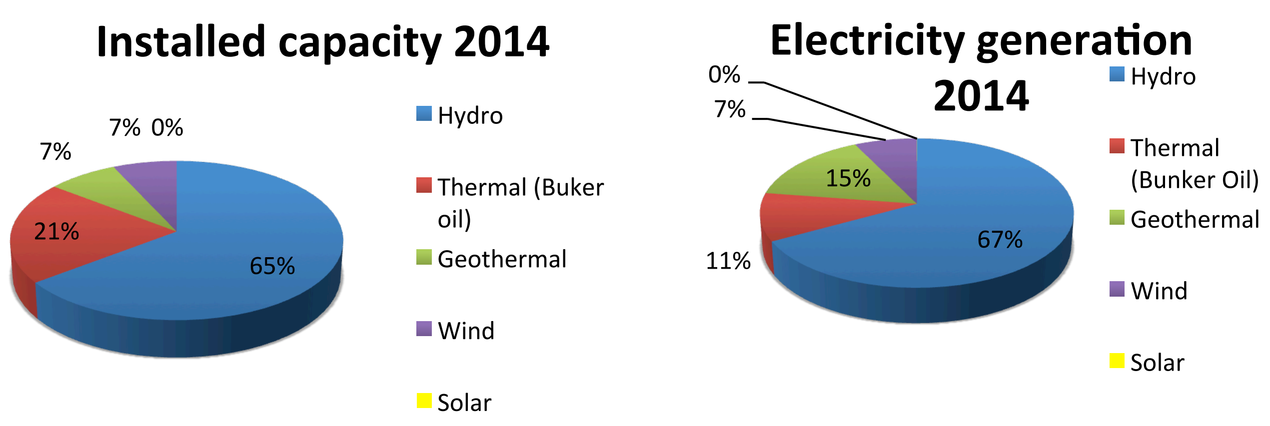


Figure 2.1: Installed capacity and electricity generation in Costa Rica in 2014. Data taken from Cepal, 2015. Chart created by author.

2.2 Organization of energy is CR

ICE monopolizes Costa Rica's electricity sector. It is an autonomous institution established in 1949 (OLADE & UNIDO, 2011, p.22). It is responsible for the development of energy, water supply, and telecommunications for the country *(Ibid)*. It is a vertically integrated company with 98.6 per cent shares owned by the government. The rest remain in the hands of private equity shareholders *(Ibid)*. ICE provided 74.13 per cent of the country's installed generating capacity in 2014. Eleven point one per cent was provided by private companies: Compañía Nacional de Fuerza y Luz (CNFL), Empresa de Servicios Públicos de Heredia (ESPH), Junta Administrativa del Servicio Eléctrico de Cartago (JASEC) (*Ibid)*. Although CNFL is a private company, and was developed to contribute to a competitive electricity market, ICE still holds a majority of its shares *(Ibid)*. There are four electricity cooperatives that service rural areas of the country. They are a part of the 11.01 per cent private generation share: Coopelesca, Coopeguanacaste, Coopesantos and Coopealfaro, 7.18 per cent was privately generated and 7.68 per cent was generated through Build Operate Transfer (BOT) agreements with private investors and ICE (ICE, 2015, p.12). A BOT is an investment model used to finance a project, where the private investor provides the financing, builds the electricity plant, and after a certain period of operation, transfers the plant to the national power organization, (Yumurtaci, Erdem, 2007, p.234), in this case ICE.

ICE's domination of the electricity market goes well beyond generation alone. The transmission grid is solely owned and operated by ICE (ICE, 2015, p.5). ICE's monopoly over the electricity sector is a large factor in the infancy of distributed generation and community power in the country.

The distribution of electricity is slightly more diverse than its generation and transmission. The majority of energy distribution is split between ICE (43%) and CNFL (34%) (Meza, 2015). The rest is divided between public companies and the electricity cooperatives *(Ibid)* (see figure 2.2). The state holds a near monopoly in the generation, transmission and distribution of electricity in the country. Moreover, ICE's ownership of CNFL's contributes to its controlling an even larger share of the energy market. Figure 2.3 illustrates the control of generation, transmission and distribution energy markets in Costa Rica. Regulatory bodies in Costa Rica's energy market include Ministry of Environment, Energy and Telecommunications, and the Public Service Regulating Authority.

2.2.2 MINAE:

The Ministry of Environment, and Energy (MINAE), is responsible for planning the national energy sector and for the development of energy policies in Costa Rica (OLADE & UNIDO, 2011). MINAE developed the "National Energy Plan 2015-2030", which outlines the future energy targets for the country and methods to achieve them (MINAE, 2014).

2.2.3 ARESEP:

The Public Service Regulating Authority (ARESEP, 2015), is responsible for fixing and monitoring electricity prices and rates, and enforcing standards of quality, quantity, reliability, continuity, timing and optimal provision of public services, including electricity supply in stages of generation, transmission, distribution and marketing *(Ibid)*.

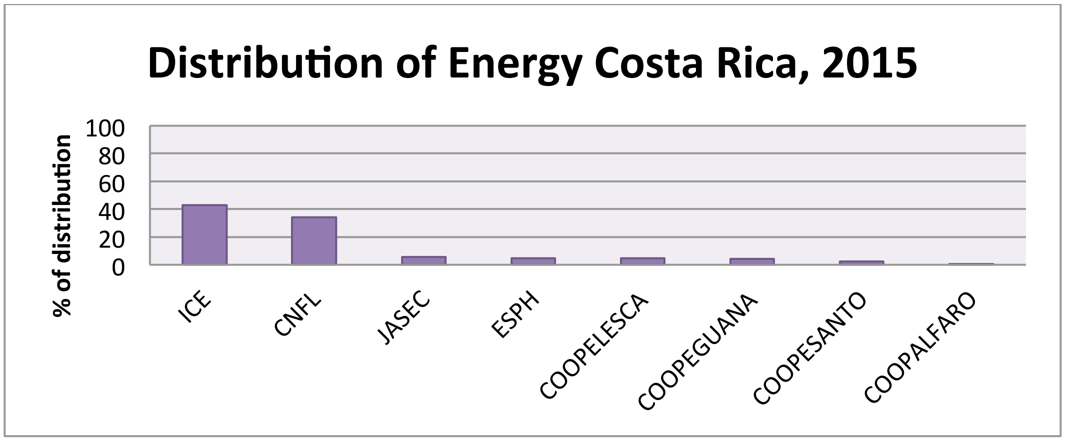


Figure 2.2: Energy distribution in Costa Rica, 2015. Data taken from Meza, 2015. [Graph made by author.]

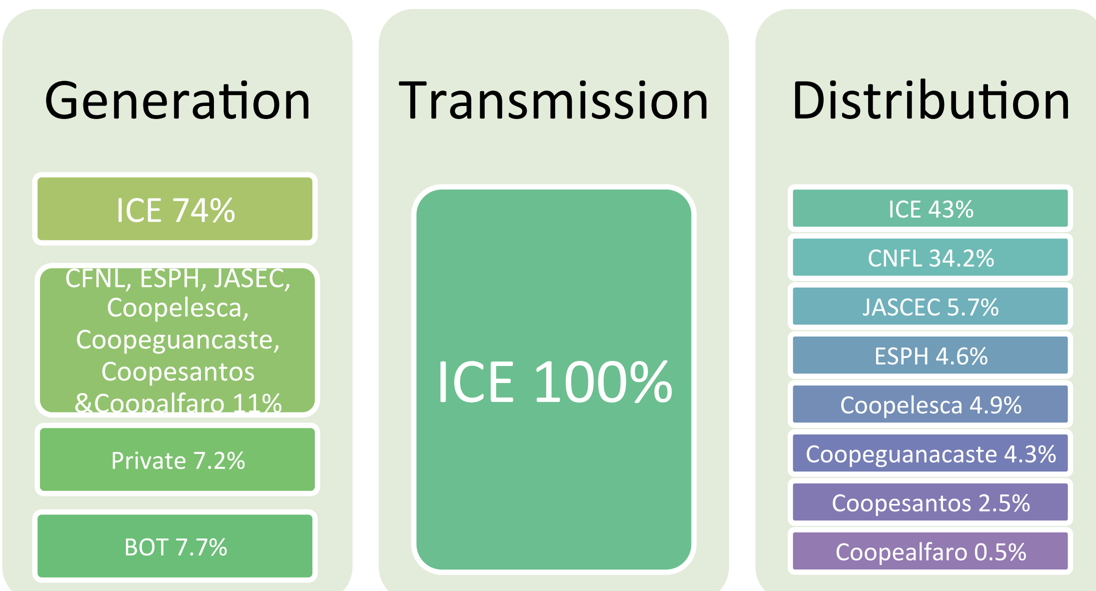


Figure 2.3: Energy generation, transmission and distribution in Costa Rica, 2015. [Graph made by author, Data taken from OLADE & UNIDO, 2011]

2.3 Transmission grid

The National Interconnected System (SIN) is owned and operated by ICE, and uses two voltage levels, 230 kV and 138 kV. The SIN runs a total of 850 km, with 25 substations at 138 kV, running a total of 480 km and 16 substations at 230 kV (Elrich, Krost & Wilch, 2010, p.4). Figure 2.4 shows the layout of the national grid with its various substations. Most of the energy is consumed in the central part of Costa Rica (marked *center* in map), where two large hydro generators are present. The other large generators are located outside of the central area. This can contribute to energy loss through lengthy transmission lines.

SIN connects to the Central American Electrical Interconnection System (SIEPAC), which connects six countries and their electricity markets: Guatemala; El Salvador; Honduras; Nicaragua; Costa Rica and Panama (Economic Consulting Associates, 2010, p.1). SIEPAC serves over 30 million people with over 1800 km of 230 kV transmission lines (Economic Consulting Associates, 2010, p.25). The purpose of SIEPAC is to allow neighbouring countries to purchase and sell electricity during peak times and low generation, as well the power to optimize the use of shared hydropower resources.

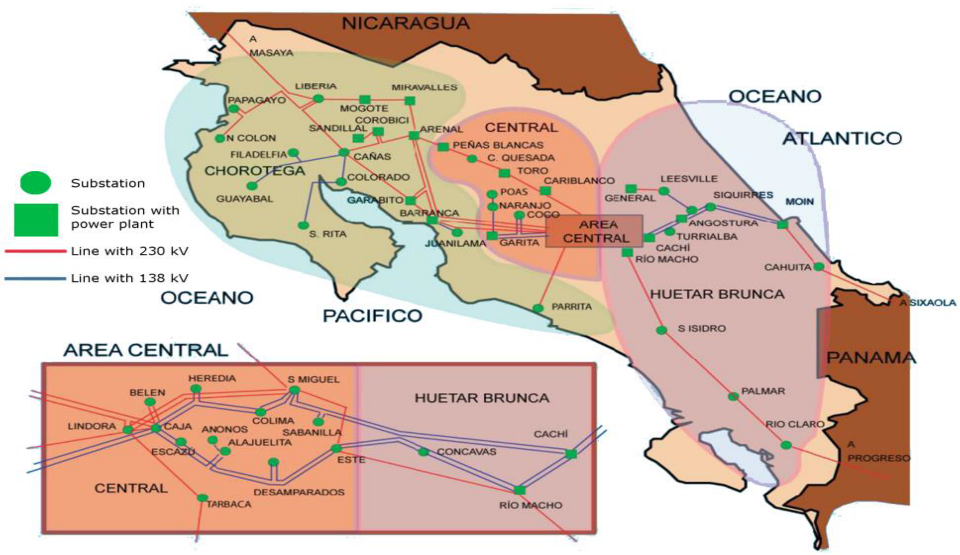
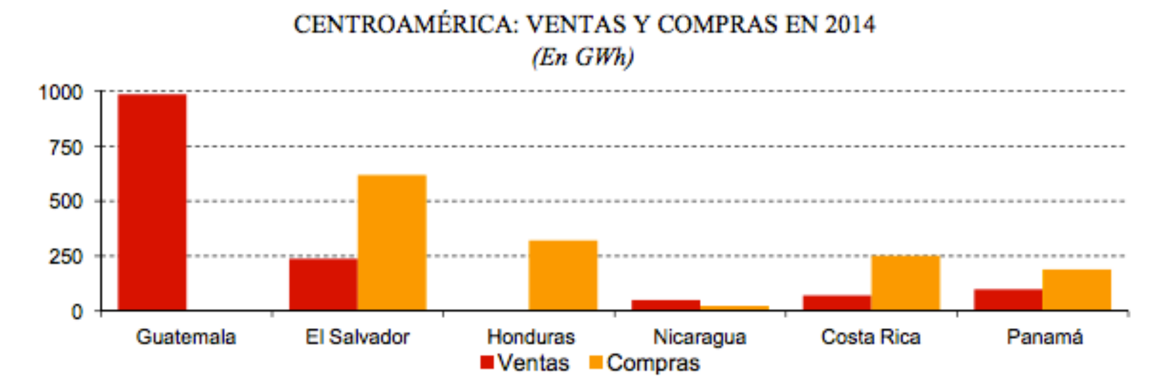


Figure 2.4: Map of national transmission (SIN) lines in Costa Rica with substations (Weigl, 2014).

In 2014, Costa Rica imported 251,526.4 MWh, and sold 68,749.4 MWh of electricity through SIEPAC (Cepal, 2015). A large amount of the imports occurred between the months of January and May, during the country's summer/dry season. The highest exporting months were

July and December, during Costa Rica's rainy season. Figure 2.5 illustrates electricity imports and exports in 2014 in Central America via SIEPAC. Appendix 2 illustrates historical trends of this data. Figure 2.6 illustrates monthly variance of electricity imported versus exported in 2014 for Costa Rica. Appendix 3 shows historical trends for this data.



Fuente: EOR, reportes diarios del último día de cada mes de las transacciones regionales en el MER.

Figure 2.5: Central America's electricity sold and purchased in 2014 (Cepal, 2015).

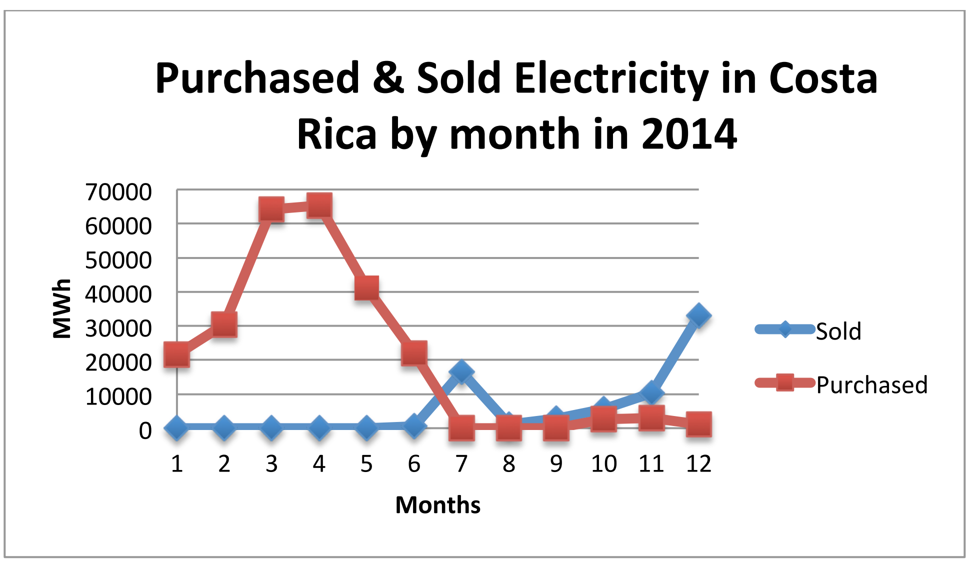


Figure 2.6: Costa Rica's electricity sold vs. purchased by month in 2014. Data collected from Cepal, 2015. [Graph made by author]

The country's distribution grid runs a total of 22,719 km, and is controlled primarily by ICE (77 per cent of it is owned by ICE) (IDB, n.d). The distribution infrastructure faces problems of meeting expected demand growth and reducing electricity loss. In order to increase reliability and efficiency the system requires rebuilding existing circuits and constructing new feeders *(Ibid)*. According to the World Bank (2015), electricity losses during transmission and distribution are 11% in Costa Rica. This is lower than neighbouring countries such as Panama at 13% and Nicaragua at 15% *(Ibid)*. Although electricity losses remain low in Costa Rica when compared to other neighbouring countries, distributed generation would help in further mitigation of energy losses due to the proximity of generation and distribution systems.

2.5 MW installed, capacity, growth of energy demand, future goals

Costa Rica's installed generating capacity in 2015 was 3,035 MW, with a maximum demand capacity of 1,632 MW (Cepal, 2015). The country was able to meet its demand capacity, and totaled 10,118.4 GWh generation in 2014 *(Ibid)*. Most of the energy demand occurred in the residential sector. In 2010, 40 per cent of energy consumption occurred at the residential level, see figure 2.7 (ICE, 2015).

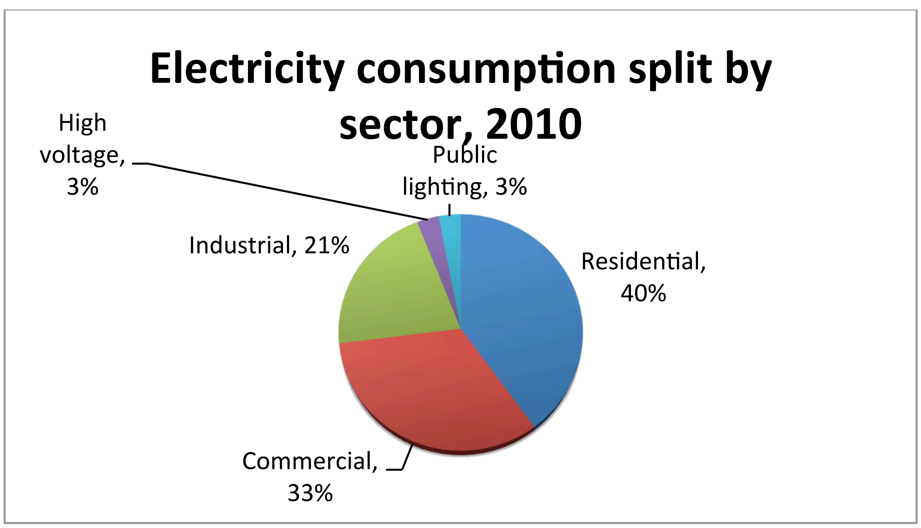


Figure 2.7: Electricity consumption split by sector in 2010. Data provided by ICE, 2015.[Graph made by author].

According to the MINAE's National Energy Policy, total power consumption has grown at an average annual rate of 4.4 per cent in the last 25 years (2014, p.35) (see appendix 4 for graph of this data). As energy demand increases, Costa Rica will need to explore methods of energy efficiency, demand response strategies, as well as expanding its energy generation capacity. It would be beneficial to look at community energy as a model to address these needs, while, simultaneously addressing the economic, and social concerns of communities. Figure 2.8 shows the future installed capacity plans of the country in its National Energy Plan, split by energy source. It is unclear where solar fits in the plan. Wind, biogas and solar are grouped together in the graph labeled green.

Costa Rica: installed capacity and projected by source type in the National Energy Plan 2015-2030

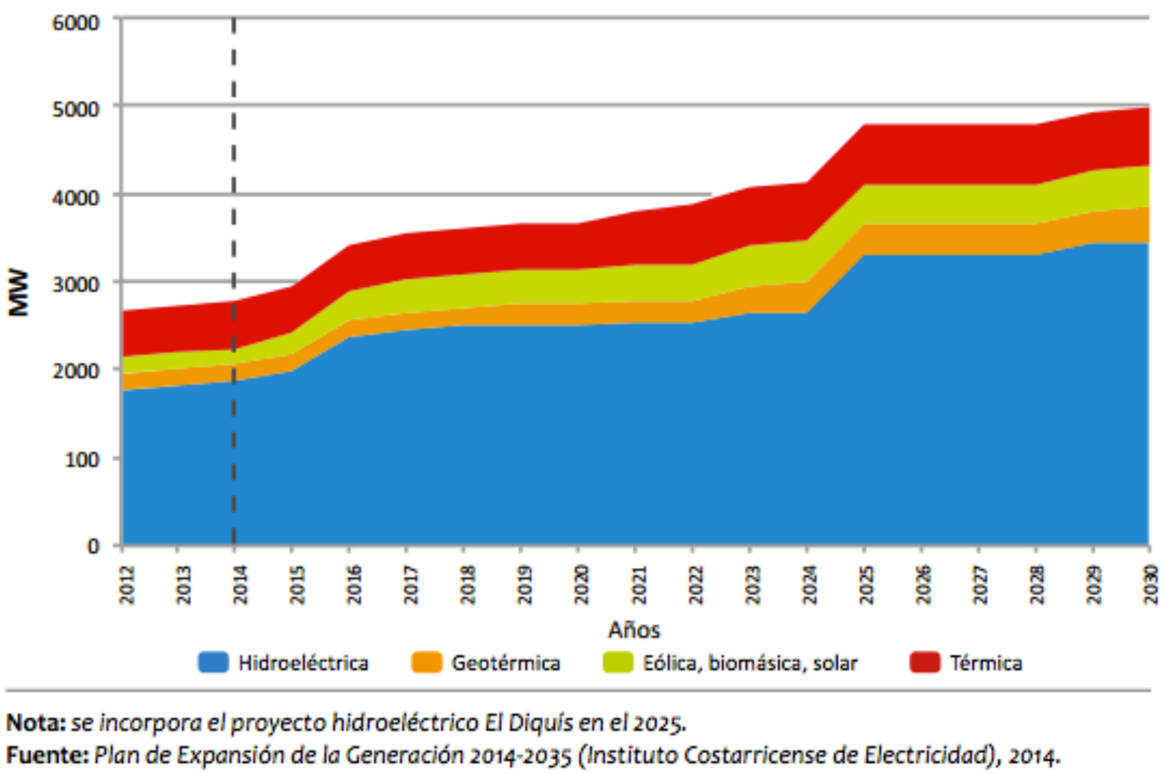


Figure 2.8: Future installed capacity goals of Costa Rica from 2015-2030 split by energy generation source (MINAE, 2014, p.39).

The National Energy plan developed by the MINAE uses the Electricity Generation Expansion Plan developed by ICE as a framework for the country's energy plan. In the expansion plan, ICE aims to increase the country's installed capacity to 4,304 MW by 2024 (ICE, 2012, p.6). In order to do this, the plan shows a continued reliance on hydropower. Hydro will remain at 72 per cent of installed capacity. There is only a slight increase in wind and biomass from 7 per cent to 8 per cent installed capacity by 2024 *(Ibid)* (see appendix 5 for a detailed table for future plans for each energy source). Solar energy plays a minor role in this plan, with no indication of competing significantly in the national energy market according to ICE's Expansion Plan 2012-2024.

2.6 Main players in ownership – Hydro – ICE

In 2015 there were 33 operating hydropower plants in Costa Rica (see appendix 6 for list of hydropower plants). There are plans to expand 4 plants by 2025 that would provide an installed capacity of 1,063 MW. ICE would carry all responsibility for ownership and operation of these plants (ICE, 2012). The development of the new hydro plants, alongside the projected development of 100 MW of wind and 105 MW of geothermal power would help bring the installed capacity to 4304 MW by 2030 *(Ibid).* ICE holds a large portion of the existing hydro production, owning and operating 1048 MW of the 1818 MW total capacity (*Ibid)*.

All of the hydro dams operated by ICE classify as large hydro dams, which means having the capacity of more than 30 MW (Energy Gov, n.d). Large hydro dams are more detrimental to the surrounding eco-systems, particularly to rivers, due to their massive size, holding large amounts of sediments back and causing disruption to natural habitat (International Rivers, n.d). Less than half of the hydro plants in Costa Rica are considered to be small. Fourteen out of 33 hydro plants are less than 30 MW (ICE, 2012), categorizing the rest as medium or large plants. Even the smallest hydro dams can make a river inhospitable to native flora and fauna, while displacing entire indigenous communities (Lindo, 2006, p.299). During the construction of

Penas Blancas hydroelectric dam, there was a massive release of sediment, which caused death to thousands of flora and fauna *(Ibid).* Environmental damage from hydro dams can be intense in Costa Rica, because there is no law limiting the number of dams per watershed. There is a law that strictly limits the energy production capacity of a project, leading to multiple limited size power plants that intensify cumulative environmental damage on the watershed *(Ibid).*

The displacement of Indigenous communities also poses a serious issue with the development of large hydro dams proposed by ICE. The Diquis hydroelectric project will be the largest in Central America, with a generation capacity of 631 MW. The project will displace over 1,500 indigenous people and flood 915 acres of indigenous territory (Sutch, 2011, p.29). In total the dam will flood 6002 ha of land, impacting 108 archeological sites, and cost $3 billion USD (Americas, 2016). Despite indigenous protests, according to ICE, Diquis power plant is scheduled for completion in 2020 (Meza, 2014). ICE's involvement in the development of controversial hydro projects brings into question the interests of the state in developing its distributed energy sector.

2.6.2 Financing for hydro plants

Current financing models of hydro production in Costa Rica could also play a role in the stagnant development of community power models. Most hydro dams have been financed through the Inter America Development Bank (IDB) (Montero, 2016) and World Bank (World Bank, 2016). Most recently, IDB approved financing for the Reventazon hydro project, totaling a $200 million USD loan that is to be paid back over a 20-year term (IADB, 2016). The total cost of the project is estimated around $1.4 billion USD, which is on the high end of hydro projects in Central America (World Bank 2015). The high development costs of energy projects impact capital components such as rate of depreciation, and return on investment (World Bank, 2015). The existence of these extremely large loans could be factors for the lack of distributed energy generation systems and continued support for institutionally owned energy systems. The funding issue could also explain for the lack of energy efficiency programs, and time of use electricity rates in the country.

Although ICE has financed many of its hydro projects through these institutions, ICE needs to invest over $8 billion USD into the energy sector over the next twenty years in order to meet increasing energy demand (World Bank, 2015, p.64). This is challenging as the country's policies and regulations are not set up to attract private sector participation, and are limited through its BOT and independent power producers schemes *(Ibid)*.

2.7 Solar Energy in CR

The current installed capacity of solar in Costa Rica is 1 MW. This represents less than 0.1% of the country's energy mix. In 2014 solar generated 1.5 GW of energy (Cepal, 2015). Solar Miravalles Park represents the 1 MW generation. It was built in 2012 and is located in the northern part of the country. The project is owned and operated by ICE, through a $10 million grant that was given by Japanese Ministry of Environment, Energy and Telecommunications (Chan, 2012). There is one other solar project that is also owned and operated by ICE. The Sabana project was built in 2012 and has a capacity of 3kW. This is a very small project that consumes the energy generated right on site (Smart Grid, 2012). Currently, these are the only two solar projects that generate energy in the country, other than private solar generation. The government has developed other programs to deliver power to remote communities through the

Rural Electrification Plan, and to develop the solar industry in the country through its Decentralized Energy Generation Plan.

2.7.1 Rural Electrification

In 1998, ICE developed the Rural Electrification with Renewable Energy Sources Plan. The aim of this program was to provide remote communities access to electricity through the use of off-grid PV systems or micro hydro. ICE developed this in its determination to make Costa Rica 100% electrified (ICE, 2011). The program was developed as a solution to the high cost of expanding the transmission and distribution grid to reach these communities. The program would also help minimize CO_2 emissions through the use of clean energy, in contrast to the sources of energy these communities had been accustomed to using (*Ibid*). These include the burning of wood, garbage and kerosene. The plan aimed to reduce an estimated 210 thousand tons of CO_2 emissions during the duration of the program, which ran from 1998 to 2009 *(Ibid).*

The program was not free for communities, but did provide an attractive package. ICE would provide the solar PV systems to the customers, in return for a small fee of $2 USD per month, including replacement of the battery (Weigl, 2014, p.26). Unfortunately, due to the lack of education given to the customers on how to use the equipment, many systems malfunctioned and were returned to ICE *(Ibid).* This program was the beginning of the solar industry in Costa Rica, but has not expanded much since its launch. Figure 2.9 indicates the locations of the solar PV installations through the project. The project was able to reach 1072 households, installing a total of 1500 panels, with a peak capacity of 140 kW (ICE, 2015). Although micro-hydro development was also supported through this program, only one project was actually installed, is indicated in blue on the map.

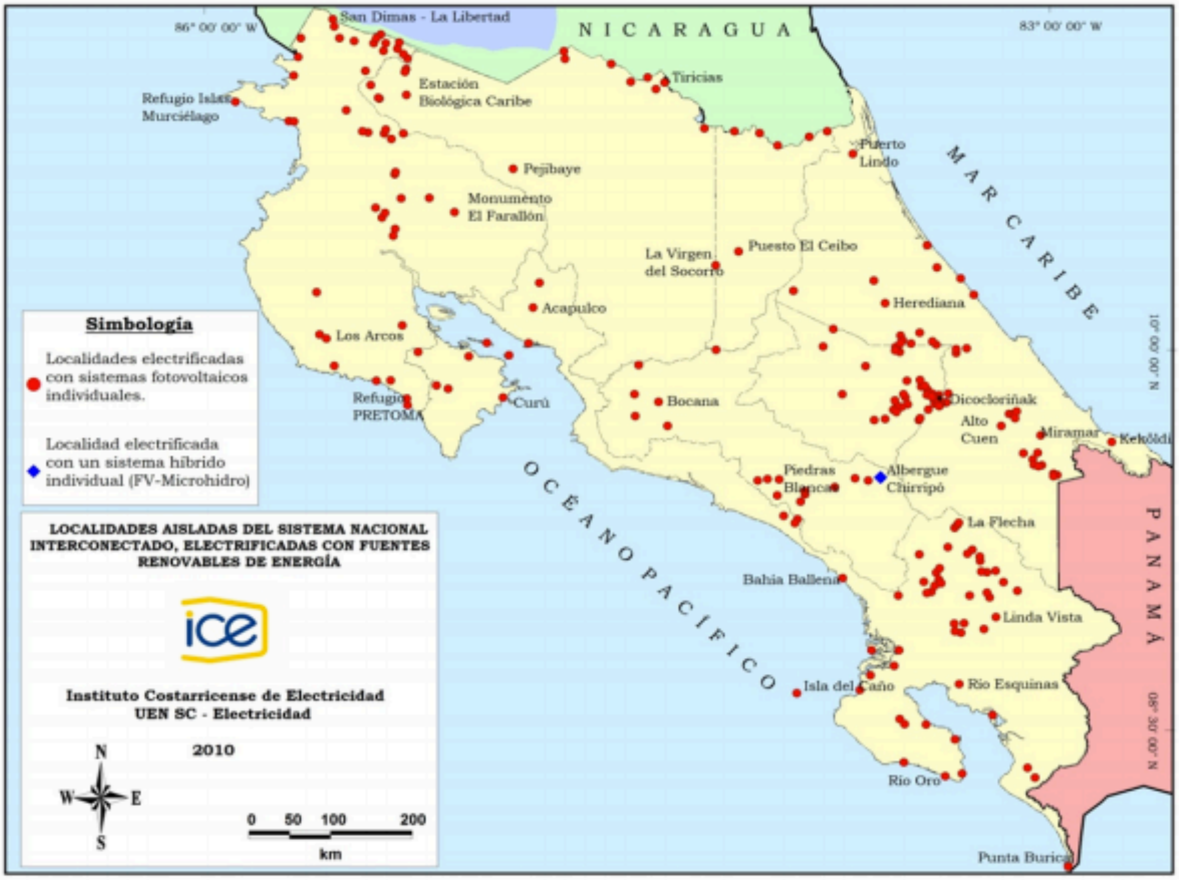


Figura 4-8 Ubicación de localidades con equipos aislados

Figure 2.9: Locations of ICE's Rural Electrification Program of PV and micro-hydro (ICE, 2015).

2.7.2 Decentralized Energy Generation- Plan Pilito Generacion Distribudia

In addition to rural electrification, in 2010 ICE initiated the Distributed Generation Pilot Plan where rural residential and small business could connect renewable sources such as solar, wind, micro hydro and biomass to the power grid, via a two-way meter (Stuch, 2011, p.27), known as net metering. This was a pilot project and was discontinued in February 2015, after reaching its maximum capacity, and reporting tremendous success (Fornaguera, 2015). The initial program was to run for two years, allowing a maximum capacity of 5 MW. However, due to its success, the program was extended in 2012 for another three years with a target capacity of 10MW. Of this, 1 MW was reserved for residential installations (ICE, 2011). By the end of the program, 366 applications were received with a total of 11,274 KW installed. 6,759 kW were solar and the rest hydro and wind power (MINEA, 2014). The terms of net metering in the Pilot Program would allow customers to consume any energy they generated and feed excess energy into the grid, and yield from the grid when needed. The grid essentially would act as a source of free energy storage for the customer. However, ICE would not pay the customer for the electricity generated and fed into the grid (Weigl, 2014, p.27). The generator was provided with a contract with ICE for 15 years, that would reset the meter balance to zero on an annual basis, not allowing excess energy to be carried over to the next year *(Ibid).* The maximum installed capacity allowed in any residential or commercial unit was based on the average electricity demand over the year *(Ibid).* Customers were not allowed to install more than their average electricity demand from the previous year.

This program has now expired. The MINAE developed a new distributed energy generation program in March 2016. The new net metering program was developed to complement MINAE's Energy Plan 2030 goals. The National Energy Plan VI 2012-2030, had set targets for solar energy to supply 1.3% of the energy mix (MINEA, 2011). However, another National Energy Plan 2015-2030 was drafted in 2015, but provided no detailed targets for solar energy generation in the national energy supply (MINEA, 2014). The plan does make reference to solar energy having a potential of 120 MW, but no clear protocol on expanding on this potential are given. Solar energy is deemed as an intermittent source by MINEA *(Ibid).* The plan does expand on one solar energy project to be completed by 2018, a 5MW project to be completed by the electricity sector *(Ibid).*

2.7.3 New Net Metering Policy- distribution electrification

In March 2016, ARESEP released the new distributed generation program for Costa Rica. Under the new program, energy generators will now have to pay an interconnection fee to the distribution companies for feeding excess energy into the grid, while self-consumption from generated energy is free (ARESEP, 2015). This is different than the previous net metering program where generators could feed electricity into the grid at no cost. The interconnection fee varies with each LDC (see table 2.1), approximately $0.02 to $0.05 USD for each kWh fed into the grid (meter running backwards). Regular users of the grid must pay anywhere from $0.15-$0.27 USD per kWh (ICE, 2016). Essentially, with this new program, these users would be saving $0.15-$0.12 USD per kWh consumed during zero production times (ARESEP, 2015). The program is open to solar, hydro, biomass and wind generation.

This is far from the FIT policies currently enacted in Canada and Europe, where energy generators are paid for the energy they feed into the grid. Additionally, in Costa Rica, those interested in generating their own energy are required to pay a fee to their power company to conduct a feasibility study, interconnection, additional inspection fees, and the cost of a two-way meter (Arias, 2016). See figure 2.10 for set up costs by LDC.

<u>Tariffs for distributed generation</u>

Power Company	Tariff per kWh Colons ₡	Tariff per kWh $ USD[2]
ICE	28.3	0.05
CNFL	28.0	0.05
JASEC	14.6	0.03
ESPH	11.6	0.02
Coopelesca	29.4	0.055
CoopeGuanacaste	21.3	0.04
CoopeSantos	29.7	0.056
CoopeAlfaro	28.6	0.05

Table 2.1: Tariff for distributed generation fed into the grid by LDC (ARESEP, 2015).

[2] USD rates are based on latest bank rates of 535 CC X 1 USD

Set up/feasibility costs of LDC

Power company	Feasibility study	Interconnection	Additional Inspections
ICE	¢90,000	¢80,000	¢80,000
CNFL	¢35,000	¢90,000	¢30,000
JASEC	¢25,000	¢75,000	¢22,000
ESPH	¢30,000	¢70,000	¢25,000
Coopelesca	¢33,000	¢98,000	Varies by region
CoopeGuanacaste	¢11,000	¢49,000	¢11,000
CoopeSantos	¢25,000	¢53,000	¢20,000
CoopeAlfaro	¢20,000	¢52,000	¢33,000

Figure 2.10: Set up costs by LDC for distributed generation (Arias, 2016).

The average Costa Rican family consumes 250 kWh per month (TNI, 2011). Hypothetically speaking, if the generator was providing 50 per cent of this requirement, and was feeding excess energy into the grid at $ 0.05/kWh, they would save $31.25 USD per month. This amounts to a yearly savings of $ 375 USD. This would mean a payback period of 16 years, with a solar installation cost of $ 61100 USD (Solar Energy Costa Rica, 2016). An analysis of this calculation at the community level will be conducted further on.

$$s = (a*n) - (b*r)$$

a: amount of electricity fed into the grid with PV system (assuming 50%)
b: amount of electricity taken form the grid (normal case)
n: net metered cost per kWh fed into the grid
r: rate of electricity from grid
s: savings

$$(125 \times 0.05) - (250*0.15)$$

S= $31.25

The current net metering program is merely that, a *program*, not a law. But this is subject to change. Costa Rica has a tradition of formulating laws, instead of policies in its energy sector.

A common apprehension among Costa Rican lawmakers is that if policies are formulated, they may change with the introduction of new governments (J. Montero, personal communication, February 20th, 2016). There is a working group formulating the Distributed Energy Law for Costa Rica.

The lack of flexibility that comes with the development a law versus a policy may hinder the success of distributed energy generation in Costa Rica. As with new technologies such as renewable energy, their applicability and success is unknown, especially in a country such as Costa Rica with limited experience with distributed generation. There must be a "tradeoff between the credibility of the regulatory commitments and the flexibility required to accommodate unforeseen circumstances and changes in the interest of the various actors" (Millan, 2006). A law that would be constructed around distributed generation in Costa Rica should be credible and flexible. Nonetheless, this may not be possible with "ideologically" laden initiatives such as renewable energy. A policy may be more beneficial.

2.8 Cost of electricity and percentage of energy distribution in CR by distributor

The cost of electricity in Costa Rica varies with each LDC, the type of consumer (residential or commercial), and the amount of electricity consumed. Tables 2.2 and 2.3 expand on the different tariffs for residential and commercial customers.

Residential tariff rate by LDC

LDC	CR Colons	CR Colons	Tariffs in $ USD
ICE	First 200 kWh 79.26	> 200 kWh 142.88	0.15: <200 kWh 0.27: >200 kWh
CNFL	Min 3,679.20 (30 kWh)	>30 kWh 122.54	Min 6.9 (30 kWh) 0.23: >30 kWh
JASEC	<200 kWh: 73.58	>200 kWh: 90.07	0.14: <200 kWh 0.17: <200 kWh

ESPH	<200 kWh: 64.70	>200 kWh: 83.65	0.12: <200 kWh 0.16: >200 kWh
Coopelesca	<200 kWh: 70.02	>200 kWh: 88.01	0.13: >200 kWh 0.16: <200 kWh
CoopeGuanacaste	<200 kWh: 67.95	> 200 kWh: 95.79	0.13: >200 kWh 0.18: <200 kWh
Coopesantos	< 200 kWh: 82.61	>200 kWh: 133.70	0.15: >200 kWh 0.25: < 200 kWh
CoopeAlfaro	< 200 kWh: 61 (2010)	> 200 kWh: 83 (2010)	0.11: <200 kWh 0.16: >200 kWh

Table 2.2: Residential tariffs in Costa Rica by LDC in 2015 (data taken from each distribution company, graph made by author).

Commercial tariff rate by LDC

LDC	<3000 kWh	>3000 kWh	USD
ICE	119.39	71.43	0.22: >3000 kWh 0.13: < 3000 kWh
CNFL	73.83	73.83	0.19: >3000 kWh 0.14: < 3000 kWh
JASEC	104	62.16	0.19: >3000 kWh 0.12: < 3000 kWh
ESPH	89.23	50.19	0.17: >3000 kWh 0.09: < 3000 kWh
Coopelesca	91.01	74.01	0.17: >3000 kWh 0.14: < 3000 kWh
CoopeGuanacaste	63.50	63.50	0.12: >3000 kWh 0.12: < 3000 kWh
Coopesantos	159.79		0.30 kWh
CoopeAlfaro	89 (2010)	53 (2010)	0.17: >3000 kWh 0.10: < 3000 kWh

Table 2.3: Commercial tariffs in Costa Rica by LDC in 2015 (data taken from each distribution company, graph made by author).

2.9 Important laws/policies in CR that govern energy:

There are many different regulatory frameworks that govern the energy sector in Costa Rica. Majority of them are laws, with few national plans and policies in the energy sector. Of the most important laws, Law *7200, 449, 7593 & 8345* all assist in shaping the energy policy framework in Costa Rica. The National Energy Plan, Carbon Neutral Plan 2021, and ICE's Expansion Plan 2012-2014 also help in shaping the energy market in the country.

2.9.1 Law 7200

This is perhaps the most important energy law in Costa Rica. It controls private participation in the electricity grid, giving authority to only ICE for purchasing electricity in the country. All electricity generated by private participants must be sold to ICE. It cannot be resold to the grid. It limits the maximum private generation capacity to 15 % of total national capacity, and to plants no larger than of 20 MW (Carls, Haffar, Jones, Morey, 2011) with a time period not exceeding 20 years (The Legislative Assembly of the Republic of Costa Rica Law 7200). Amendments to this law allow for an additional 15 per cent of national capacity to be BOT plants that produce a maximum of 50 MW (Carls, et al., 2011). BOTs allow private companies to build and operate electricity plants, operate them for 15-20 years and sell them back to ICE *(Ibid)*.

The limitations of this law create significant inefficiencies in the electricity sector. Many actors capable of producing more than 20 MW cannot do so due to the restrictions of the law. El Viejo, a sugar refinery that produces energy from sugar cane waste has the capacity to produce 27 MW. However, it can only inject 18MW into the grid after consuming energy for its own use (O. Sanchez, personal communication, February 23th, 2016) due to the boundaries of Law 7200. Currently, El Viejo has a 10-year contract with ICE, which will expire in 2017. Renewing the contract appears to be a problem for ICE (*Ibid)*. The current contract prices each kWh produced by El Viejo and sold to ICE at 10 cents USD per kWh *(Ibid)*. This rate is not constant and fluctuates on a yearly basis.

Law 7200 poses limitations to the amount of energy private generators can produce. In addition, they must wait for ICE to accept the bid; ICE has no obligation to do so (Lokey, 2009).

2.9.2 Law 449

Law 449 delegates the responsibility of the electricity sector planning to ICE, which is autonomously owned by the state. This Law grants ICE the responsibility for developing the energy sector in Costa Rica, with a focus on hydropower in order to strengthen the national economy and promote greater good for Costa Rica (The Legislative Assembly of the Republic of Costa Rica Law 449)

2.9.3 Law 7593

Law 7593 defines electric power as a public service and states that the generation, transmission, distribution and commercialization of power is to be regulated by ARESEP (the Legislative Assembly of the Republic of Costa Rica Law 7593). It establishes social equity, environmental sustainability, energy conservation and economic efficiency as the central criteria's for establishing fees and rates for public service (*Ibid*).

2.9.4 Law 8345

Law 8345 is a more recent law that provides for the participation of four cooperatives in rural electrification and LDC's in national energy development. It outlines the legal framework for governing, generation, distribution and sale of electricity using renewable and nonrenewable energy sources (Carls, et al., 2011). It allows for rural electricity cooperatives and municipal companies to generate electricity for their customers without size limitations and sell excess electricity to ICE *(Ibid).* Cooperatives and LDCs are the only ones that have the authority to sell electricity directly to their consumers (*Ibid).*

2.9.5 National Energy Plan

The National Energy Plan 2015-2030 was developed by the MINEA in 2015. It establishes the main guidelines for the development of the energy sector in Costa Rica moving forward. The plan seeks to expand on energy generation, promote energy efficiency, develop infrastructure for energy generation, transport and distribution, open the market for participation by the private sector, and to develop regulatory framework that will support its plans by 2030 (MINEA, 2015).

2.9.6 Carbon Neutral Plan 2021

Cost Rica aims to be the world's first country to become Carbon neutral by 2021. The Carbon Neutral Plan 2021 will focus on offsetting Costa Rica's emissions through its forestry sector, bringing its net emissions to 2005 levels (UNFCC, 2015). In order to achieve carbon neutrality, Costa Rica will have to introduce greater solar and wind energy capacity into its current and future goals. Future installed energy capacity for thermal generation still constitutes 15%, and less than 100 MW for solar (ICE, 2012). Costa Rica will need to develop its energy, transport, and agriculture policies in order to reach its C-Neutral goal, as these are still in "embryonic stage" (Climate Action Tracker, 2015).

2.9.7: ICE Expansion Plan 2012- 2014

This plan aims to increase Costa Rica's generation capacity to 10,148 GWh with an emphasis on hydropower generation, particularly the development of the Diquis hydro project (ICE, 2012). The project would impact Indigenous land. It would be the largest of its kind in Central America. ICE has faced continuous opposition from indigenous communities. However, the Diquis hydro plant shows no signs of discontinuing. The plan indicates the potential for 1700 MW hydroelectric development projects. Many of these proposed projects are located on indigenous land, causing complexities that lead to unattainable potential *(Ibid)*. Additionally, 780 MW is located in national parks, where the law does not allow for the exploitation of the land *(Ibid)*. In this result only 50 per cent of the hydro potential can be realized *(Ibid)*.

In the plan, there is no proposal put forth for community energy planning. Yet, community energy planning may alleviate some of the concerns that stem from the current model of energy development in Costa Rica, while simultaneously stimulating social, economic and environmental attributes. The following chapter will describe the communities chosen for the case study.

3. Alexander Skutch Biological Corridor

The communities of the Alexander Skutch Biological corridor sit on the Talamanca range (Daugherty, 2002), Quizarra and Santa Elena are located in the southern part of the country, in the province of San Pedro (see appendix 7 for location of communities). The communities are closely situated to the Chirripo National Park, which connects to La Amistad, an international biosphere reserve that joins into Panama (FES, 2016). La Amistad is the largest protected rainforest in Cost Rica, with an enriched and extremely bio diverse ecosystem (Cost Rica Guide, 2016). It also acts a bird sanctuary, home to over 285 bird species (Montoya & Martinez, 2015).

The incredible biodiversity of the communities lends further credence to sustainable energy development in the area. The main river, Rios Penas Blancas, runs through the corridor, connecting the different communities and acting as a source of social and ecological livelihood for the community members. In Costa Rica Biological corridors act as habitats that connect various forest fragments and minimize habitat isolation (Wang, 2008). Further, "they have been proposed to reduce the impact of fragmentation on tropical rain forests, to preserve habitats, and to allow species migration, dispersal, and colonization" (Wang, 2008).

The corridor is the subject of a joint research development project between the Tropical Science Center of Costa Rica and the Faculty of Environmental Studies, with a focus on the conservation of regional biodiversity and sustainable development (Daugherty, 2002). York University has been present in the communities since 1998 (FES, 2016), with annual visits from students through a summer course organized by the faculty. The summer course provides the students with an opportunity to stay with a family and learn about the corridor and way of life of the Costa Rican people through experiential learning.

The ASBC connects forest fragments from the highest elevations to those near the Pacific coast in the low lands. This highland- lowland connection is significant as the lowland forests are the most threatened ecosystems in Central America (Daugherty, 2002). Furthermore, the watershed of the ASBC connects to the Mesoamerica Biological Corridor; a Pan-Central American project that connects from Panama to Mexico (Daugherty, 2002). The diversity and ecological importance of the ASBC make conservation and sustainable development extremely important for the communities.

York University's relationship continues to strengthen in the communities of the ASBC. In April 2016, York University opened the Lillian Meighen Wright Eco-Campus. The facility will attract local, national, and international researchers who share a common interest in encouraging and researching education, neo-tropical conservation, community well-being, sustainable livelihoods, eco-health and sustainable development (FES, 2016). As part of this eco-campus, the research done for this study will act as a foundation for understanding energy needs, and possible energy development, in the community.

3.1. The Communities

According to the National Institute of Statistics and Census (IEC), approximately 2,250 people live in the communities of Santa Elena, Quizarra, Cruce and Penas Blancas. Of this approximately 700 reside in the two case study communities (EIA, 2011). There is a general balance between the percentage of men and women in the communities, approximately 52 per cent are woman, and 48 per cent are men (EIA, 2011). Of this, 55 per cent of the habitants are aged 0-29, with the ages of 10-19 accounting for the highest portion. Adults from the ages of 30 and 59 account for 34 per cent, and older adults account for 11 per cent of the population (EIA, 2011). The primary occupation of the community members is overwhelmingly in agriculture.

Education levels of the community members are as follows: five per cent of the population does not possess any degree of schooling; and 28 per cent of the population have completed primary school. Five per cent of the population has completed only secondary school, and 11 per cent has completed some degree of post-secondary education. (EIA, 2011).

The main agricultural activities consist of sugar cane and coffee farms. A majority of the male population works. Most females perform domestic work within their own homes, or act as domestic helpers in others. They refer to themselves as "housekeepers" in survey responses. The general culture of the communities is focused around a family oriented livelihood. There is little new economic development in the communities. In 2011, only 30 per cent of the population considered themselves to be employed, whereas 46 per cent were inactive, or unemployed (EIA, 2011).

Despite low levels of economic development, there is strong participation of community members in cooperative organizations such as CoopeAgri; a coffee production cooperative; ASADAS a water management cooperative, AMUQ an association of local women who undertake organic farming and AMESE-association of local women who have established a cooperative that developed and operates a local bread shop. See Figure 4.7 for graph of cooperative participation. Of the 51 households surveyed, 27 were members of one or more of the above cooperatives. This information suggests that there is a strong commitment to collective and local participation in decision-making. Participation in cooperatives promotes development that is not only societally centered (Pieterse, 2001) but is also democratic in nature (Burkey, 1993; Carmen, 1996; Ife, 2002). The pre-existing involvement of the community members in cooperatives creates a socially attractive environment for community energy cooperatives to develop. However the low economic development and status of the communities may hinder the financial aspects of a co-op. Although cooperatives are considered an effective "participatory strategy to bootstrap low income people into the socio-economic mainstream" (Majee & Hoyt, 2011, p.48), this community may even fall beneath the *low-income* level. Bootstrapping it into a socio-economic mainstream may be difficult without external financial assistance, despite its pre-existing social participatory values.

3.2. History of the communities

The community has a history of opposing the development of hydro projects. In February 2013, ICE proposed the development of the "Penas Blanquitas" hydro project by the company *Hydroelectrica Bueanos Aires,* in the ASBC (EIA, 2011). The project was to produce 3.8 MW of energy, from the Río Peñas Blancas (EIA, 2011). However, this project did not proceed after lengthy environmental assessments pressed for by the community members.

When speaking to the community members about the proposed project, all 51 respondents were opposed to it. Many of the reasons for not wanting the project were related to the negative impacts on the ecology and way of life of the locals: "the hydro project was not good, it would have killed our culture and society" (respondent A, personal communication, February 10th, 2016), "the river is a part of the healthy environment of the mountain and our community, our water is clean and potable, it would not be this way with the hydro dam" (respondent B, personal communication, February 10th, 2016). Other respondents mentioned the importance of the biological corridor, "the hydro dam is bad for the community, and we should be taking care of the biological corridor" (respondent C, personal communication, February 10th, 2016). Some deemed the river an integral part of their culture and entertainment, expressing in disregard "they *(ICE)* want our water, our water is for consumption and entertainment" (respondent D, personal communication, February 10th, 2016). During the proposal, community members formed a group of 5 members that set out to challenge the proposal for the hydro project.

Luis Mongel, a local environmental advocate, was one of the leaders of this group, relating the story of defeat with great emotion and pride. In the beginning of the journey, the group was weak, and unfamiliar with the bureaucratic processes. After months of research and personal investments into the legal processes, the group came together to revise and criticize the original environmental impact assessment. They developed an additional document that supported the conservation of the biological corridor, outlining the diversity of species that would be negatively impacted if the project were to proceed. In the end the project did not proceed, and the group received support from other organizations, including York University, that wanted to ensure the conservation of the land.

As a result of this, an organization called *Rios Vivos "The Living Rivers Movement"* was formed. Members of the Rios Vivos consist of lawyers, teachers, biologists, artists, housekeepers, and farmers (Rios Vivos, n.d). Rios Vivos mission is to fight against the development of hydro projects in the area of Perez Zeledon, Buenos Aires and Coto Brus, and preserve the rivers as an essential part of their lifestyles and agriculture *(Ibid).* To date, the organization has opposed the development of 16 hydropower projects in the region *(Ibid).* According to Luis, Rios Vivos is regularly invited into public consultation on the development of future hydro projects in the country.

Understanding the history of this community and their resistances to the development of the hydro project, gives even more credibility to community energy. The model could act as a tool of resistance, strengthening the community's position on the hydro dam. Community energy could simultaneously address some of the social, economic and environmental themes that are so important to the community. Community energy could also contribute to a climate change resiliency strategy, providing an energy source and ownership model that could deliver energy independence, while using renewable energy that is efficient and resistant to climate change impacts.

3.3. Community Energy in the global context

Community energy has been successfully deployed in countries with similar economies of Costa Rica. Understanding the success factors in these regions will help to understand the best practices needed for success in Costa Rica.

In 2005 Pembina institute conducted a “Best Practices Case Study” on five communities in India, Kenya, Sri Lanka, South Africa and Bangladesh, and found the following practices as key success factors in each case study:

- The need for existing infrastructure and enabling policies
- Assessment of projects
- Choice of energy technologies
- Community ownership and structure
- Funding and financing (Pembina, 2005, p.1)

In all five communities there was an already pre-existing institution or organization that was present, that made the deployment of energy projects easily accessible, and contributed greatly to their success. Having existing organizations such as local NGO’s or community groups within the community can help facilitate engagement with local members much more effectively *(Ibid)*.

A *Needs Assessment* for the project is crucial to understanding the energy needs of all community members. In the project in Kenya, women’s needs were not given priority, and this was outlined as an issue in the project (Pembina, 2005, p.17). In the case communities, energy needs of women and men are both analyzed.

Choice of energy technologies refers to the process of developing expertise gradually around renewable energy technologies. Pembina institute recommends demonstrating the benefits of renewables with a low cost energy product, such as a small solar powered lamp, then progressing onto more complex products such as solar PV lighting for a home.

In the study of the ASBC communities, the author introduced low cost energy savings products by donating LED lights to all 50-survey respondents in the community. This was a method of demonstrating energy efficiency and introducing new energy technologies to the community. Providing the community members with LED lights would act as a first step to increasing energy awareness, and educating the community on alternative methods to reduce their energy consumption and become energy efficient. The light bulbs provided consumed 7 watts, compared to the average 100-watt light bulb that was found in most households. Packs of three light bulbs were given to each household. Although this wasn't enough to retrofit entire homes, it was enough to increase energy efficiency in the most utilized areas. Energy efficiency has been identified out as the first step to transitioning towards a cleaner economy, Amory Lovins outlined energy efficiency to be "the world's biggest untapped energy source" (2008), and began the negawatt revolution, which put importance on energy efficiency, and the concept of using each watt saved as a "commodity", which could ultimately "represent a trillion-dollar-a-year global market" (1990, p.23). Lovins deemed electricity efficiency as "the only policy that makes economic sense" *(Ibid)*. Increasing energy efficiency was the regarded as the first step in exploring green energy technologies in this community.

In the case study of Bangladesh, local women were also the owners of a lighting enterprise. This increased their involvement in the enterprise and contributed positively to its maintenance (Pembina Institute, 2005, p.5). In this community, Pembina Institute found that women who owned and operated the enterprise showed improvements in their quality of life, as well as social status in the community *(Ibid).* Projects in South Africa and Kenya both identified community ownership and an "existing spirit of community cooperation" as success factors in the development and operation of their energy projects.

The development of community owned enterprises was repeatedly found to be an important structure for the success of rural energy projects in all five communities. Cooperative ownership structures create a sense of local ownership, which encompasses democratic processes, and interest is maintained throughout the life of the project. Additionally, Pembina Institute noted the need to have external bodies that can provide funds for the installation and maintenance of a project to make it successful (Pembina Institute, 2005, p.10).

When renewable energy projects are set up using the cooperative model, they tend to offer many benefits to the local community. These include: local income generation through returns on investments, local approval and planning permissions; local control; lower energy costs and reliable supply, ethical and environmental commitment; and load management (Walker, 2008, p.4402). Cooperatives create local awareness around renewable energy projects, as they are locally owned and operated. They also provide a "clear link between local generation and local consumption" (Parker, 2009, p.2089). An energy transition is very difficult without a "shift in the nature or pattern of how energy is utilized within a system" (Araujo, 2014). This shift can occur more efficiently when there is local participation in energy projects. The importance of involving the community in developing an energy project effects the success of the project, and therefore must be considered an important factor for expanding the in the renewable energy market in Costa Rica.

3.3.1. Dharnai, India: Solar PV

The importance of community involvement can be demonstrated through a closer investigation of a solar PV project that was deployed in Dharnai, India. The community of Dharnai can be differentiated from the communities of the ASBC, in that it did not previously have access to electricity. However, the participation of community members in the energy project was reoccurring theme that was present in this case study as well. In 2014, through the Greenpeace Energy Access Campaign, Greenpeace set up a pilot microgrid in the village of Dharnai, Bihar, India. The project supplied electricity to 1, 500 villagers, who had no access to electricity for 30 years (Greenpeace, 2014, p.28). Much of the income of the village comes from agriculture, so electricity needs were quite low, only needing to power the homes and streetlights of the village. A microgrid is different than other renewable energy projects, as it can behave as a generator, or a load, on the electricity grid. In this manner, microgrids can participate in wholesale markets to supply energy to a network, and act as self-sufficient islands when needed (Jayawardena et al., 2015, p. 497). Greenpeace started a pilot project in Dharnai, to showcase to policy makers the types of regulatory frameworks, and financial mechanisms that would be required in order to upscale the concept to other parts of India (Greenpeace, 2014, p. 8).

The project was successful, in supplying 100 kW of energy through 280 solar panels that generated enough electricity to supply 400 households *(Ibid)*. Greenpeace covered the initial costs, and villagers paid fees for the use of electricity. Being a community led project, there was certain ambitions and awareness around the project. The project was led by electrification committees, which consisted of members of the village, BAZIX and Centre for Environment and Energy Development (CEED). BAZIX is an institute that promotes livelihood, and aims to improve the quality of life of poor households across the world *(Ibid)*. CEED represents a network of NGOs that specifically provide grassroots-level support, and helped connect the community to the project *(Ibid)*. Greenpeace played an active role in training the members of the community so they would be well versed, in maintaining and operating the micro grid. Engagement with community members was identified as a crucial influencing factor in the events that followed after the initial organizations had left.

To this day the project is still operational, and community members are continuing to be actively involved in the maintenance, operation and governance of the project. Gaps identified in the project pertain to limited government resources, as Greenpeace funded the project solely. Limited institutional involvement level is common in many rural electrification projects (Prayas, 2012, p. 4). The success of this project can be linked to the involvement of community members, the goal of delivering energy to an area once not electrified, and the involvement of NGOs. Understanding the success factors in this particular case study will be useful in developing a community energy model for the ASBC. The importance of community engagement and the involvement of external bodies and resources are identified as essential components of community energy success.

The following chapter will analyze the survey responses and assess the energy needs of the ASBC community.

4. Data Results

In the case communities, over half of the community members surveyed were women. Only 36 per cent were males. The difference in gender of the participants could influence other answers in the survey.

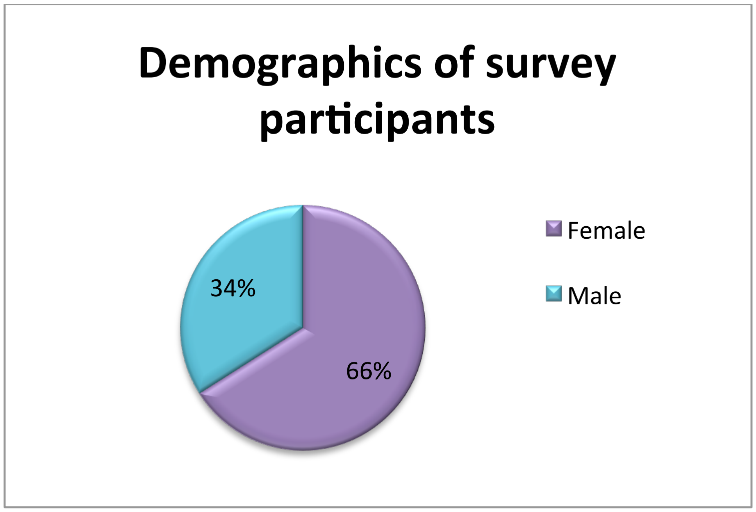


Figure 4.1 Gender demographics of survey participants (Data sourced from Ghuman, 2016).

Fifty-one households were surveyed, 66 per cent of survey respondents were from Santa Elena, and 34 per cent were from Quizarra. (See appendix 8 for a map of households surveyed in each community). The respondents were not surveyed equally from each community, due to the difference in the population of the two communities. Survey respondents showed a strong sense of relationship to their communities. 86 per cent of the respondents had lived in their community for 10 or more years. Due to the geographic location of the communities, ICE is the energy distributor in the region, (see appendix 14 for survey questions and responses).

4.1. Energy Use:

Of the 51 households surveyed, the consumption of energy per month ranged from 56 kWh to 395 kWh, (see appendix 9 for graph of energy consumption per household). The average low to medium income household in Costa Rica consumes 250 kWh per month (TNI, 2011), The average household in the communities consumes 182 kWh per month. This is well below the national average, and below the subsidized energy rate per kWh that ICE charges. ICE charges a subsidized rate of ₡ 79.60 CC per kWh for residential customers who consume less than 200 kWh a month. Customers who consume more than 200 kWh per month pay ₡ 142.88 CC per kWh. According to the data, 58 per cent of households use less than 200 kWh per month, receiving the subsidized energy rate, (see figure 4.2). It should be noted that data collected for energy consumption is based on respondents' answers, not electricity bills.

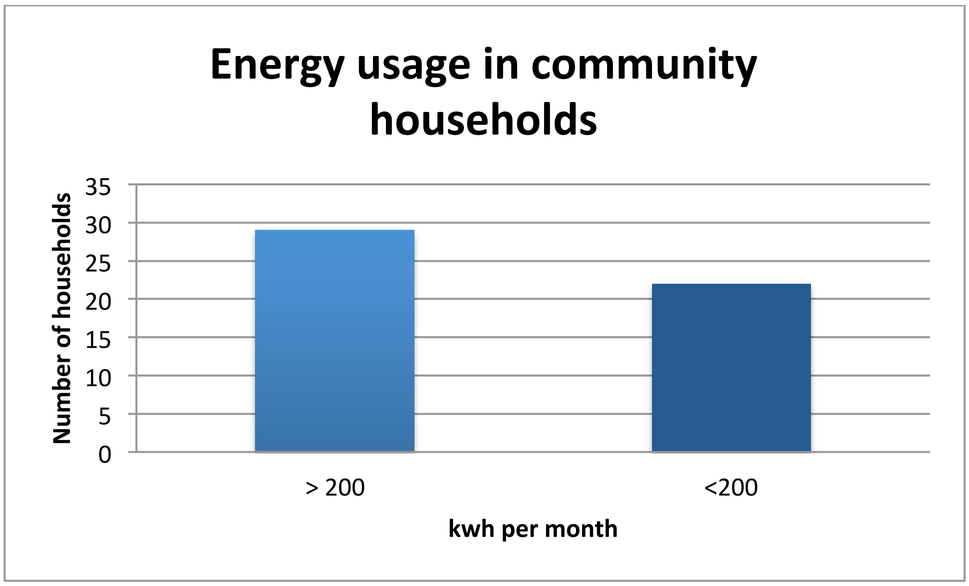
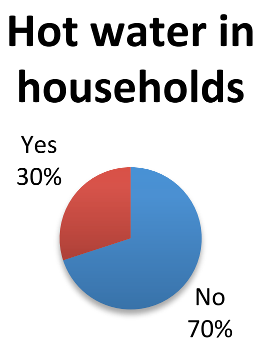


Figure 4.2: Graph of number of households that use </> 200 kWh of energy per month [Data sourced from Ghuman, 2016].

Hot water consumption was not a priority for respondents. 35 out of 51 households did not have hot water in their homes. The most common reason for not having hot water was "its not necessary". The other reason was that hot water is "too expensive", (see figures 4.3 and 4.4).



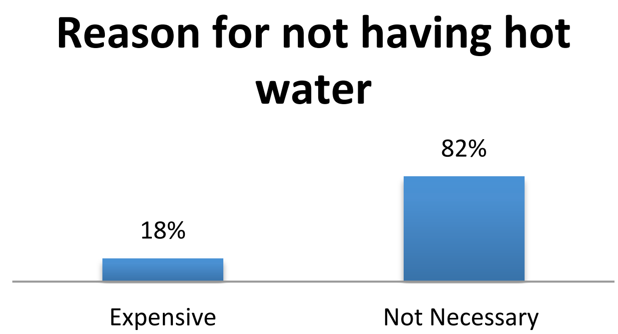


Figure 4.3: Percentage of households with hot water in the communities [Data sourced from Ghuman, 2016].

Figure 4.4: Reasons for not having hot water

A combination of energy sources is used for cooking in the community, (see figure 4.5 for graph of different energy sources used for cooking in community households). Thirty one percent of households use a combination of electricity and gas as a source for cooking, 17 per cent use a combination of all three energy sources: gas, electricity and wood for cooking. The high cost of electricity can be linked to the use of several energy sources for cooking, 21 per cent of households use electricity as main source of cooking. Generally speaking, these households are the ones with high-energy consumption, and probably higher income levels. It is surprising to see wood as an energy source for cooking. This could be due more to cultural practices than income levels.

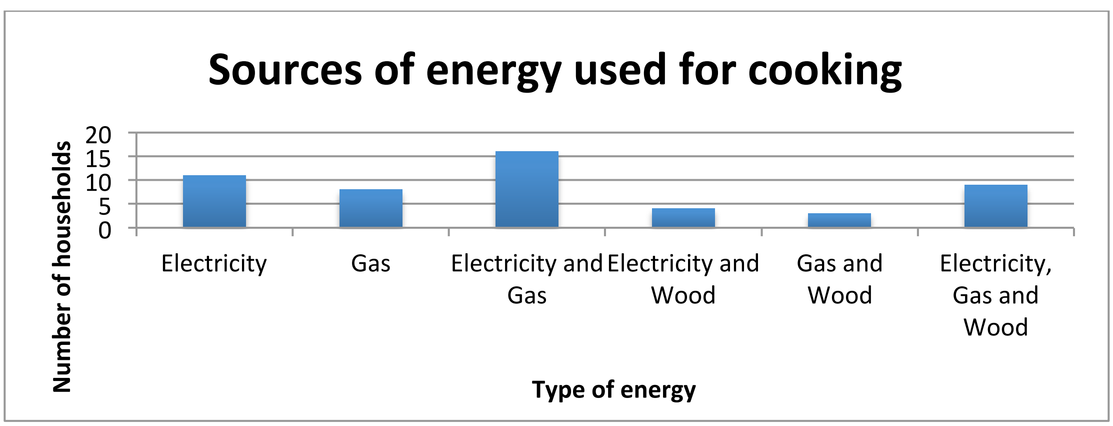


Figure 4.5: Sources of energy used for cooking in the community [Data sourced from Ghuman, 2016].

Respondents were generally happy with the reliability of their energy supply, even though 100 per cent of the respondents reported losing power at least once a month. In the rainy season, some reported losing power as much as 10 times per month, (see table 4.1 for responses on *If customers were happy with their energy supply*). The duration of the power cuts varied from 10 minutes to 3 hours. The large variation in time is dependent on the season. The rainy season is known to have more frequent and longer power cuts. Out of the 51 respondents, only 11 were not happy with the energy service, despite the frequent power outages.

Happy with energy supply	It is not reliable	Power is too expensive
40	6	5

Table 4.1: Respondents response to if they were happy with their energy supply [Data sourced from Ghuman, 2016].

4.2. Cooperative involvement

The community members demonstrated a high level of social involvement in cooperatives. Twenty-six out of 51 respondents were active members in at least one cooperative, either within their community, or in the surrounding areas. Eleven out of the 26 respondents belonged to more than one cooperative. Cooperatives include Coopeagri, Coopelianz, AMUQ (a woman's association that operates the local coffee shop), ASADAS, AMESEP, ASOCUENCA and Association of Quizarra, see table 4.2 for breakdown of each cooperative membership.

Coopeagri	AMESEP	AMUQ	Association of Quizarra	ASOCUENCA	ASADAS	Association of Desarrolo	Coopelianza
18	3	2	3	1	2	1	5

Table 4.2: The different cooperatives community members are a part of [Data sourced from Ghuman, 2016].

The high degree of cooperative involvement indicates that the community members have an understanding of how cooperatives function, and the role that the members play. These indicators could be supportive of the development of additional energy cooperatives in the community. Additionally, four of the respondents were actively involved in the opposition to the proposed dam in the ASBC. This required community members to be leaders in the development of the community group that opposed the dam. The group collaborated and worked together in building a case against the proposed dam. These factors could be highly influential in the success of a community lead project.

4.3. Interest in RE

Respondents showed a high interest in renewable energy, yet their knowledge of renewable energy technologies seemed limited. Forty-seven per cent of respondents referenced solar and natural gas as other sources of energy that they were aware of. It should be noted, that solar energy was often times referred to the use of the sun to dry clothing and food, and not solar PV. Remarkably, 6 respondents indicated no awareness of energy sources, while 13 referred to wood as an alternative, and only 5 indicated biogas as an alternative energy source, (see figure 4.6 for awareness of alternative energy sources in the community).

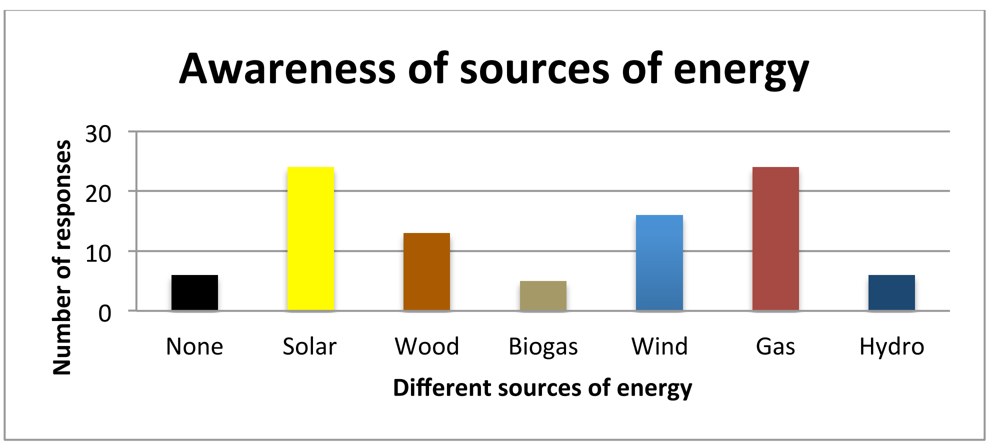


Figure 4.6: Awareness of energy sources in community [Data sourced from Ghuman, 2016].

When asked if "*they were aware that a renewable energy project could be owned and operated by the community, and the profits could go back into developing the community",* only 29 per cent of respondents answered yes. Even though this model is very similar to the model utilized in many of the organizations and cooperatives that the members already belong to, awareness on community energy projects was low. However, when asked if being a part of an energy cooperative is something that they would be interested in, 94 per cent of respondents said yes, while the rest said *no* due to unfamiliarity with the subject. Furthermore, 50 out of 51 respondents answered yes, when asked if they were interested in learning more about renewable energy. Respondents also showed a very high degree of interest in renewable energy, and the community energy model. However, interest is not the only component needed when developing a community energy project.

Education on the subject matter, and financing are among the most important components when developing a community energy project. Some would argue social acceptance is one of the most important factors in renewable energy development and is often neglected (Wüstenhagenn, Wolsink & Bürer, 2007). Many communities experience the Not In My Backyard affect, or NIMBYism. NIMBYism refers to public opposition of new developments in communities (Wright, 2004). It is common for communities to oppose the development of renewable energy projects when "trust is a key issue" *(Ibid)* between the community and the investors. According to the data collected, the case communities are experiencing a Please On Our Land (POOL) (Kruze, 2016) effect. This could be due to marketplace acceptance of renewable energy systems *(Ibid)* where the inter-community has adapted renewable energy technologies and innovations. Conversely, this may or may not be reflected in the intra community. The inter community represents the market place community, while the intra-community refers to opinions within a particular community[3]. In this case, the high acceptance of community energy in the intra-community may be reflective of the positions taken in the inter-community. Even though a community energy project may not be financially or politically feasible in the intra-community, the community is influenced by the positioning of the inter-community and its acceptance of renewable energy technologies. As the demographic analysis of the test communities unveils, only 28 per cent have completed primary school (EIA, 2011). The low education levels could indicate an enthusiastic community that is willing to learn, but also one that may be unaware of the financial and legal implications of community energy projects.

The following chapter will evaluate whether a community energy model would be feasible in this community, considering the monthly energy consumption of the members. Additionally, community energy models will be proposed that could be effective in Costa Rica.

[3] Intra-community is referred to a small group of people, a smaller community. Whereas inter-community is a larger group of people (Meyer, Woodruff, 1997). The behaviours and opinions of the inter-community may influence the intra-community. The positioning of the intra-community may not be representative in the inter-community, but it may become influenced and overshadowed by it.

5. Community Power in Costa Rica

The solar irradiance in Costa Rica as a whole presents a very strong opportunity for the development solar energy in the country, as well, as in the case communities chosen. Costa Rica receives anywhere from 1900- 2100 kWh/ m2 annually (Solar GIS, 2016). To determine if a solar community energy project is financially beneficial for the community, a cost analysis will be conducted.

5.1. Individual

To determine the feasibility of an individual home interested in installing a solar PV project, the average household consumption of 180 kWh per month will be used, at a rate of $0.15 USD or ₡ 79.66 CC.

<u>Scenario A: Current Grid tied energy system</u>
180 kWh consumed
X 79.66 CC or $0.15 USD per kWh
=$ 27.10 USD or ₡ 14,338.80 CC or per month

<u>Scenario B Solar PV system on a 7 year financing term</u>
$ 4,200 USD: Cost of 180 kWh PV system-_Polycrystalline solar panels (6 x 245wp)
+ $ 1910 USD: Cost of additional materials for installation and services
= $ 6,110 – 20% down ($1,222)
= $ 4,888 amount being financed * rate of 8 % per year[4]. For the purpose of this study the amount being financed will be rounded up to $5000.
= **$77.61**[5] cost of financing the project per month for 7 years or ₡41, 521.35

Period	Total Paid	Interest	Principal	Balance
Year 0	$0.00	$0.00	$0.00	$5,000.00
Year 1	$931.32	$373.65	$557.67	$4,442.33
Year 2	$931.32	$328.15	$603.17	$3,839.16
Year 3	$931.32	$278.94	$652.38	$3,186.78

[4] Rates and lease terms are based on Costa Rica Solar Solutions (Costa Rica Solar Solutions).
[5] Data calculated from Scotiabank mortgage calculator

Year 4	$931.32	$225.71	$705.61	$2,481.17
Year 5	$931.32	$168.13	$763.19	$1,717.98
Year 6	$931.32	$105.85	$825.47	$892.51
Year 7	$930.98	$38.47	$892.51	$0.00

Figure 5.1: Lease agreement payback period over 7 years [Data taken from Scotiabank, 2016]

Scenario C: Solar PV system on a 10 year financing term

$4,200: Cost of 180 kWh PV system – Polycrystalline solar panels (6 x 245wp)
+ $ 1910 USD: Cost of additional materials for installation and services
= $ 6,110 (0 % down) amount being financed * rate of 12.45% per year[6]
= $ **88.15**[7] per month of ₡ 47, 160.25

Period	Total Paid	Interest	Principal	Balance
Year 0	$0.00	$0.00	$0.00	$6,110.00
Year 1	$1,057.80	$723.49	$334.31	$5,775.69
Year 2	$1,057.80	$680.57	$377.23	$5,398.46
Year 3	$1,057.80	$632.15	$425.65	$4,972.81
Year 4	$1,057.80	$577.50	$480.30	$4,492.51
Year 5	$1,057.80	$515.85	$541.95	$3,950.56
Year 6	$1,057.80	$446.27	$611.53	$3,339.03
Year 7	$1,057.80	$367.77	$690.03	$2,649.00
Year 8	$1,057.80	$279.20	$778.60	$1,870.40
Year 9	$1,057.80	$179.25	$878.55	$991.85
Year 10	$1,057.80	$66.43	$991.37	$0.48
Month 1	$0.48	$0.00	$0.48	$0.00

Figure 5.2: Lease agreement payback over 10 years [Data taken from Scotiabank, 2016]

Savings:

It is important to consider the amount of electricity costs that the individual would save if 50 per cent of the energy generated was consumed, and the remainder was stored onto the grid at a rate of $ 0.05 USD. The generated would save $22.50 per month if this was the case.

[6] Rates and lease terms are based on Bank of Costa Rica lease agreement (reference email)

[7] Data calculated form Scotiabank Calculator

s= (a*n) - (b*r)

a: amount of electricity fed into the grid with PV system (assuming 50%)
b: amount of electricity taken form the grid (normal case)
n: net metered cost per kWh fed into the grid
r: rate of electricity from grid

(90 kWh x $ 0.05) - (180 kWh * $ 0.15) S= $22.50 USD

Scenario A	Scenario B	Scenario C	Savings
$ 27.10 USD/ ₡ 14,338.80	$ 77.61 USD / ₡41, 521.35	$ 88.15 USD / ₡ 47,160.25	$ 22.50 USD/ ₡12,037.50

Table 5.1: Summary of current energy cost versus solar PV energy cost with 7 and 10-year lease term [Graph created by author]

Analyzing table 5.1, it can be determined, that the savings from installing a solar PV system, do not cover the high costs of installing one. It should be noted, that the above costs do not include operation and maintenance costs, and additional feasibility test costs charged by LDCs, (see figure 2.11 for fees charged by LDC). In Scenario B the customer would be paying an additional $55.11 for 7 years with the PV system, and in scenario C, the customer would pay an additional $65.65 per month for 10 years. However, after the lease agreements are paid off, the customer could enjoy access to free electricity for years after, dependent on the life span of the PV system. Scenario B has a lower cost due to a 20 per cent down payment requirement, which is not needed in scenario C, therefore the customer would have to guarantee access to these funds as well. The above scenarios also do not consider any additional energy that the customer may need from the grid during times of low production, not including the excess fed in (net metered). Depending on these factors, costs per month could vary.

Scenario A is the obvious lowest cost for the community members. However, if a member did want to invest into a project, scenario C may be the best fit, as it does not require any down payment, and comes with a 10-year lease as opposed to a 7-year lease in scenario B that does require a down payment. Even if the interest rate was set to 0.05% for a lease of $6,110 on a 10 year term, the monthly cost would still be $52.21, versus scenario A with a cost of $27.10. The customer would still be required to pay an additional $25.11 per month.

Although in the above scenarios the cost of the solar PV systems is higher than hydropower, solar PV is continuing to show cost competitiveness in the global market (IRENA, 2015). The cost of the solar PV system is relatively low. Appendix 10 provides a graph of levelised cost of electricity from various energy sources. Trends show a decrease in global PV module prices by approximately 75 percent between 2009 and 2014. Installation costs show similar trends (IRENA, 2015). The most competitive utility-scale solar PV projects can deliver electricity for approximately $0.08 USD per kWh without financial support (IRENA, 2015). This is lower than the current cost of electricity in Costa Rica ($0.15 USD). However, Central America does show some of the highest costs for solar PV when compared to other regions (IRENA, 2015), (see appendix 11 for graph of levelised cost of electricity ranges by region and technology). Higher costs in Central America could be linked to the lack of solar PV production in the region.

In order to reduce the high cost of solar PV in this community, external or internal sources of funding would be needed.

5.2. Community

If the community were to come together and develop a project, the costs of the project would be dependent on the ownership model that would be used.

5.2.1. Ownership model: Off Grid

Off grid community energy models could either be implemented for extremely remote communities with no previous access to electricity, or for high-income communities who are pursuing a move to off-grid. Since the community is already connected to the electrical grid, and transitioning towards an off-grid community requires high economic investment, going off grid is not always feasible for this community. Therefore this option will not be investigated further.

5.2.2. Connected to the grid through a microgrid

Microgrids that supply several customers by generating electricity, distributing energy and managing energy consumption while being connected to the main utility can be classified as community microgrids (Bourgeois, Gerow, Litz &Martin, 2013). Community microgrids connect several customers to one centralized mini-grid, which is connected to the main utility grid during times of low energy production (*Ibid*). This option could be investigated through a technical lens. However, due to financial limitations in the community the option may not be viable.

5.2.2.1 Micro-grid for Santa Elena

Due to the locations of the two communities, two separate microgrids would have to be developed. The 34 households surveyed in Santa Elena had an average monthly consumption of 188 kWh, which is equivalent to 2,256 kWh per year. For each customer the capacity of the energy system required to supply Santa Elena's Micro Grid will be 188 kWh per month. Assuming 4.5 hours of sun at peak power supply per day (135 hours per month), the power of the solar system required will be that of 1.4 kW (188 kwh/135h) per customer. However a 2 kW system will be selected in order to provide a large enough gap for sudden increases in energy demand. See figure 5.3 for map of micro grid for Santa Elena. The total capacity installed for the community would be a 68 kW (2 kW X 34 households).

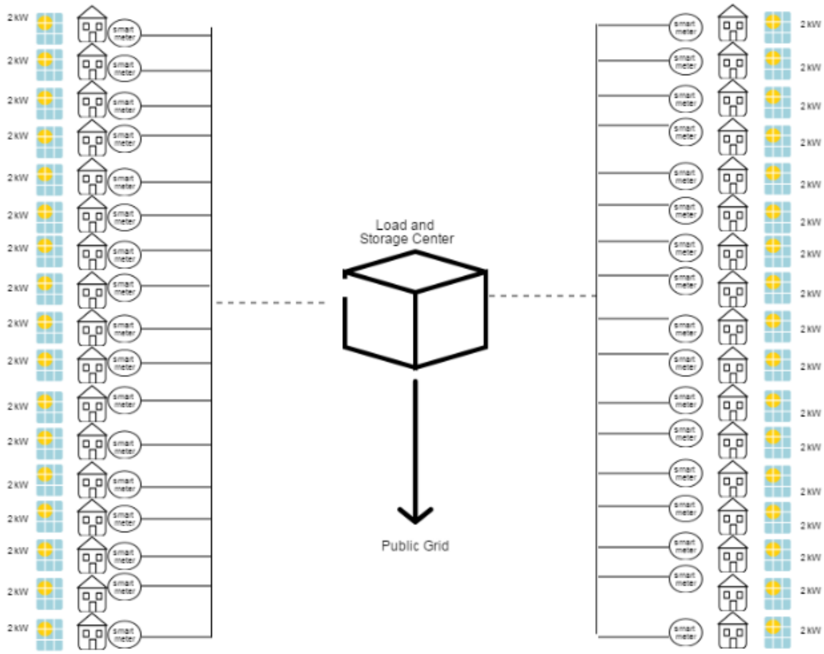


Figure 5.3: Map of microgrid proposal for Santa Elena (34 households with 2 kW solar array) [Image created by author using Picktograph].

Photovoltaic - Level 2

Resource assessment

Solar tracking mode: Fixed

Slope °: 9

Azimuth °: 0

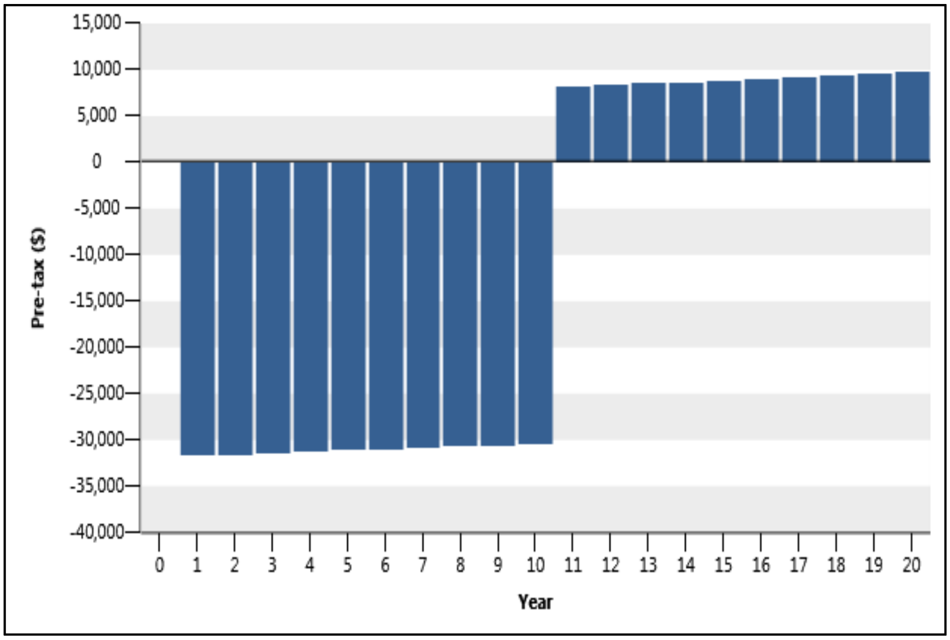
Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity rate – annual $/kWh	Electricity production MWh
January	5.86	6.31	0.10	9.675
February	6.50	6.82	0.10	9.368
March	6.65	6.75	0.10	10.255
April	5.67	5.58	0.10	8.319
May	4.82	4.66	0.10	7.259
June	4.59	4.41	0.10	6.656
July	4.64	4.47	0.10	6.981
August	4.62	4.52	0.10	7.071
Septembe	4.43	4.43	0.10	6.720
October	4.19	4.29	0.10	6.736
Novembe	4.33	4.55	0.10	6.898
Decembe	5.09	5.48	0.10	8.494
Annual	**5.11**	**5.18**	**0.10**	**94.431**

Figure 5.4: Electricity projection of 68 kW project for Santa Elena. [Data created on RETScreen].

A RETScreen analysis of a 68 kW project with an annual generation of 94.431 Mwh, (see figure 5.4 for electricity production and solar irradiance Santa Elena), concludes that the community would not see a return on investment until the 11th year. Figure 5.5 shows a cash flow graph of this project over the lifespan of the PV project of 20 years, (see appendix 12 for a complete RETScreen report prepared for the project in Santa Elena). In order to conduct the analysis, 284 units of 240 W monocrystalline silicon were used from Canadian Solar, with 14.9% efficiency. The financial data is based on financing 100% of the total cost of the project at $213,206, in this includes an initial feasibility assessment of $1,910. Annual operations and maintenance fees of the project are $2,863 per year at an interest rate of 12.5%, over 10 years. The yearly debt payment for the project would be $38,432 USD for the community of Santa Elena[8]. This ratio could be divided up amongst each household connected to the microgrid by 34 households. The above calculations also include total *revenues* of $9,443 of savings from any excess electricity injected into the grid ($ 0.10) and used at a later time. Total annual electricity injected back into the grid is 94.4 MWh. The net metering/storage charge is allocated as a revenue stream for the purpose of the calculations.

[8] These costs do not include smart meter costs and load storage center costs.



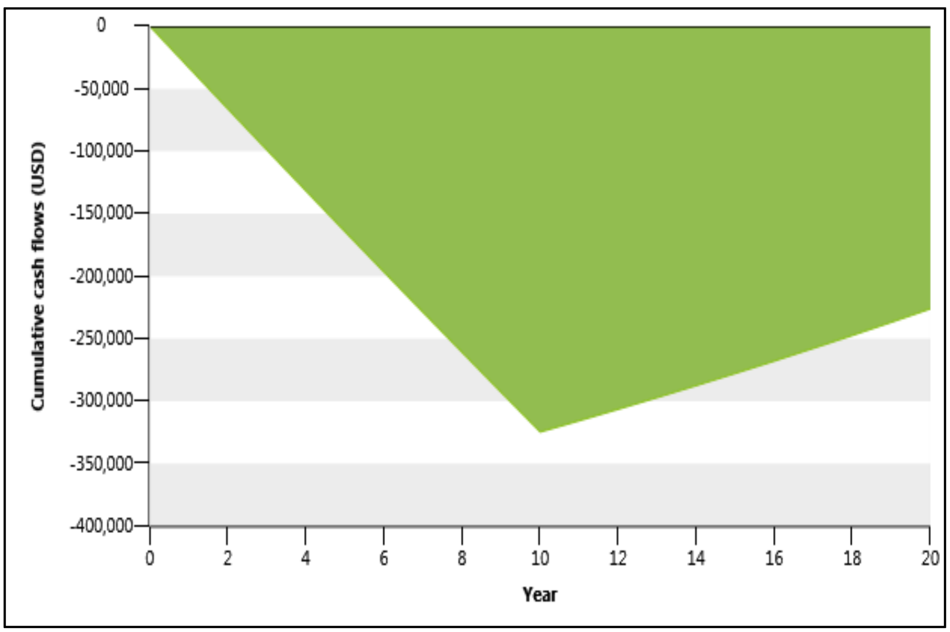


Figure 5.5: Cash flow of 68 kW Solar PV project for Santa Elena [Graph created on RETScreen]

The RETScreen analysis of this project concludes that it is indeed a high-risk project, with a simple payback period of 32.4 years and an energy production cost of $0.322. If this project were put forth, it would reduce 6.4 tCO2 greenhouse gas emissions, equivalent to 2,736 liters of gasoline not consumed. TheRETScreen analysis also shows that the highest impact variable in this project is the high initial cost, debt interest rate and the cost at which electricity is exported to the grid, figure 5.6 shows a visual of this analysis.

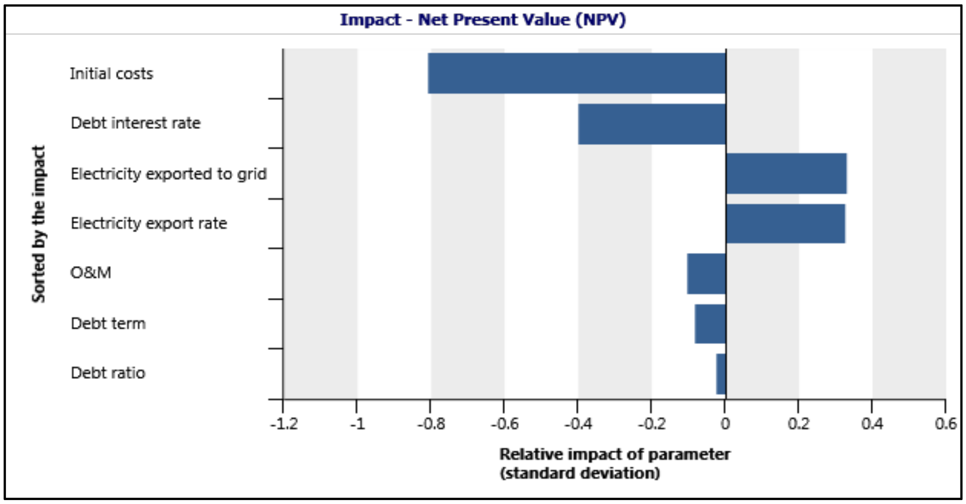


Figure 5.6: Impact analysis of Solar PV project for Santa Elena [Data created in RETScreen].

5.2.2.2 Microgrid for Quizarra

A similar microgrid analysis can be made for Quizarra. There were 16 households surveyed in Quizarra, with an average monthly consumption of 156 kWh, which is equivalent to 1,872 kWh per year, per customer. The power of the energy system required to supply Quizarra's Micro Grid will be 156 kWh per month. Assuming 4.5 hours of sun at peak power supply per day (135 hours per month), the power of the solar system required will be 1.2 kW (156 kWh/135h) per customer. However a 1.5 kW system will be selected in order to compensate for sudden energy demand increases. Figure 5.7 a map of a micro grid for Quizarra. The total capacity installed for the project in the community will be a 20 kW project. This was rounded up from 19.2 kW (1.2 kW X 16 households), in the case of sudden increased energy demand.

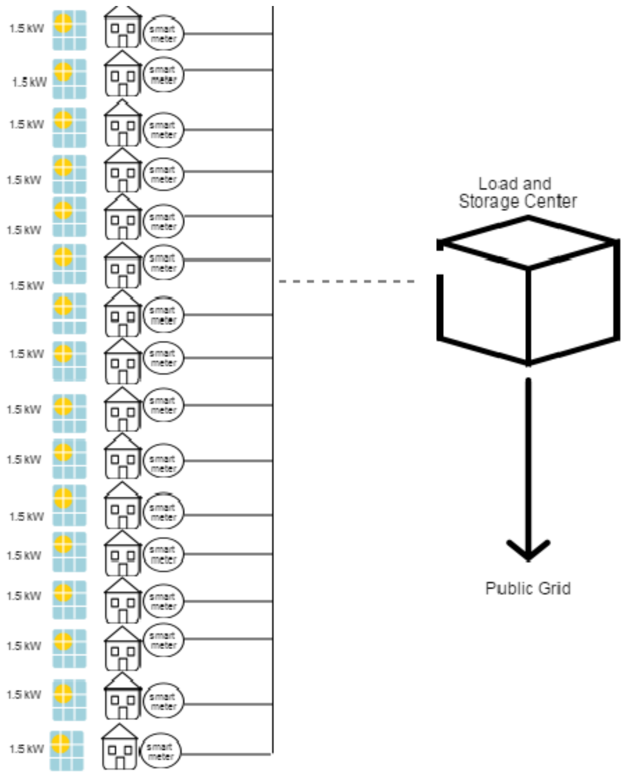


Figure 5.7: Map of microgrid proposal for Quizarra (16 households with 1.2 kW solar array) [Image created by author using Picktograph].

Resource assessment

Solar tracking mode: Fixed
Slope °: 9
Azimuth °: 0

Show data

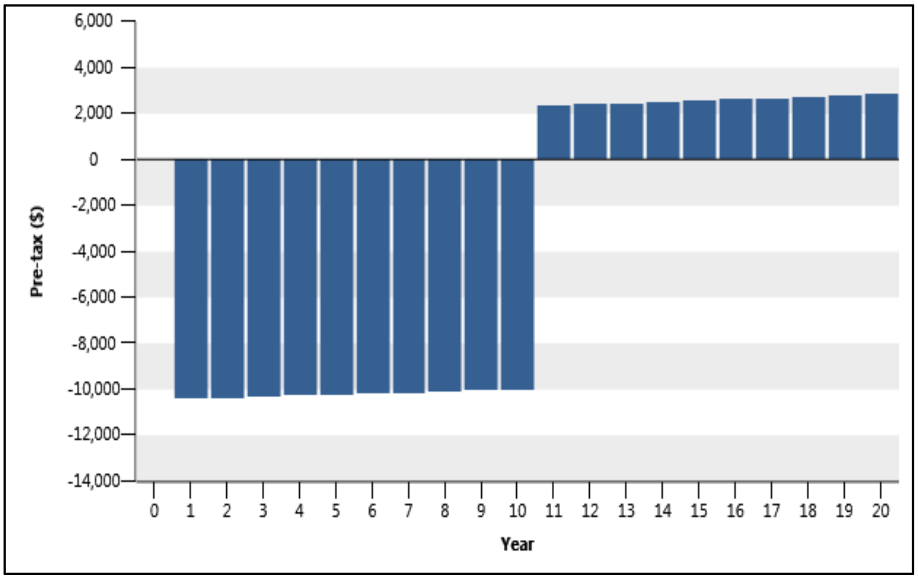
Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity rate – annual $/kWh	Electricity production MWh
January	5.86	6.31	0.10	2.861
February	6.50	6.82	0.10	2.771
March	6.65	6.75	0.10	3.033
April	5.67	5.58	0.10	2.460
May	4.82	4.66	0.10	2.147
June	4.59	4.41	0.10	1.969
July	4.64	4.47	0.10	2.065
August	4.62	4.52	0.10	2.091
Septembe	4.43	4.43	0.10	1.987
October	4.19	4.29	0.10	1.992
Novembe	4.33	4.55	0.10	2.040
Decembe	5.09	5.48	0.10	2.512
Annual	**5.11**	**5.18**	**0.10**	**27.929**

Figure 5.8: Electricity projection of 20 kW project for Quizarra

A RETScreen analysis of a 20 kW project with an annual generation 27.929 MWh, (see figure 5.8 for electricity production and solar irradiance of the project), concludes that the community would not see a return on investment until the 11th year. Figure 5.9 shows a cash flow graph of this project over the lifespan of the PV project of 20 years, (see appendix 13 for a complete RETScreen report prepared for this project). In order to conduct the analysis, 84 units of 240 W monocrystalline silicon were used from Canadian Solar, with 14.9% efficiency. The financial data is based on financing 100% of the total cost of the project at $68,438, this includes an initial feasibility assessment cost of $1,910. Annual operations and maintenance fees of the project are $887 per year at an interest rate of 12.5%[9], over 10 years the yearly debt payment for the project would be $13,223 USD for the community of Quizarra [10]. This ratio could be divided up amongst each household connected to the microgrid by 16 households. The above calculations also include total *revenues* of $2,793 of savings from any excess electricity injected into the grid ($ 0.10) and used at a later time. Total annual electricity injected back into the grid is 27.92 MWh. The net metering/storage charge is allocated as a revenue stream for the purpose of the calculations.

[9] Interest rate is based on data provided by The Bank of Costa Rica

[10] These costs do not include smart meter costs and load storage center costs.



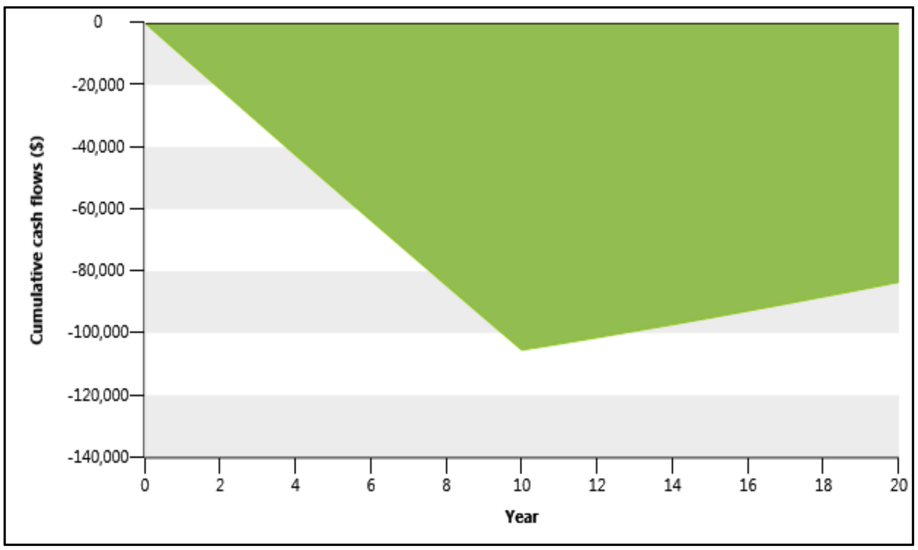


Figure 5.9: Cash flow of 20 kW Solar PV project for Quizarra [Data created in RETScreen].

The RETScreen analysis of this project concludes that it is a high-risk project, with a simple payback period of 35.9 years and an energy production cost of $0.348. If the project was put forth, it would eliminate 1.9 tCO2 of greenhouse gas emissions, equivalent to 809 liters of gasoline not consumed. The RETScreen analysis shows that the highest impact variable in this project is the high initial cost, debt interest rate and the cost at which electricity is exported to the grid, figure 5.10 shows a visual of this analysis.

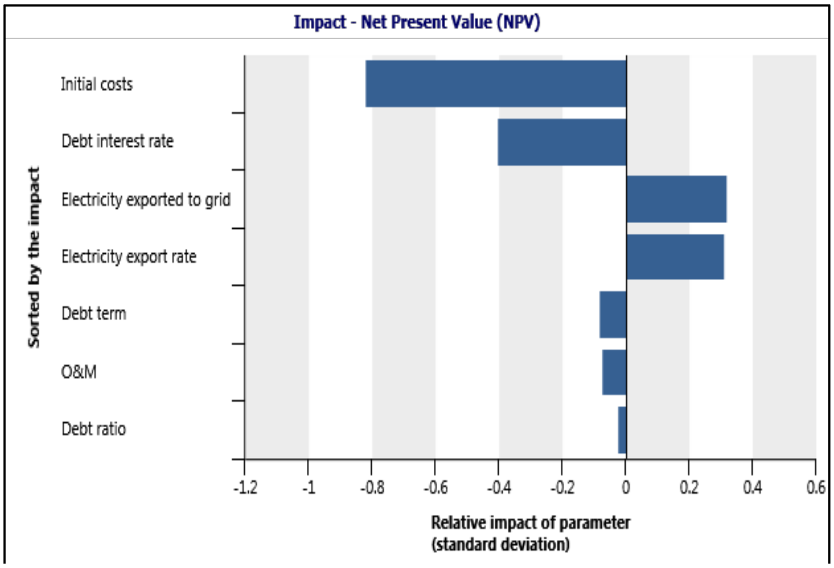


Figure 5.10: Impact analysis of Solar PV project for Quizarra

5.2.2.3 Analysis of the microgrid proposals

The above financial analyses are based on of the programed costs of materials in RETScreen *Expert*. These costs could be reduced by government incentives and lower equipment and installation costs depending on the solar installer in the country. The costs presented may not reflect the true costs of the project in Costa Rica. Currently, under Law 7447 (Regulation of the Rational Use of Energy), Article 38, the government of Costa Rica removes general sales tax, excise tax, ad valorem and specific customs tax from but not limited to: solar water heaters, water storage tanks for solar heating, PV panels, control systems for PV panels and DC to AC converters for PV systems (KPMG, 2014). These exemptions could lower the costs of the projects quoted. However, even after permutations were ran on the above simulations, both microgrids are extremely expensive, and take over 30 years for a simple payback of each project. Quizarra's payback period was higher than Santa Elena's. This could be due to the higher variable cost of installing a smaller project. Since Santa Elena had a larger PV project, the cost of the system could have been reduced by bulk purchasing. A microgird community owned project is not recommended due to the high investment costs, limited government assistance and a lack of a FIT policy.

In a political climate that does not support a FIT policy, it does not make financial sense to develop a community energy project. Without a FIT policy to generate a profit a community energy project is not possible due to the various variables discussed. Even though the above analysis does include revenue generated from net metering, this is not actually a revenue, but rather, *savings* on electricity taken from the grid. The savings do not account for the cost of the solar PV project. In order for the above-proposed projects to be financially viable, a FIT policy would have to be in place, where generators could receive $0.30-0.40/kWh injected into the grid. Only then would a community energy project make sense for the case communities.

An alternative for the communities could be to become private electricity generators under law 7200 and sell electricity to ICE. Although there is a maximum capacity of 20 MW per project, there is no specific minimum requirement for the size of the project that must be developed. However, this does not mean that there is no minimum required project size. Under this regulation, the community would have to apply as a private generator and negotiate a tendering contract for the price of each kW sold to ICE after consumption. The negotiation process could lead to disappointments for the community as they may not even be recognized as private generators, or the price per kWh may not be sufficient to generate enough profits. As mentioned earlier, the cost of electricity ranges from $0.15 -0.27/kWh. The price per kWh that ICE may pay its generators would not be higher than the cost of selling it. Here the community could use the grid to store excess energy during peak periods, and take from the grid during low production periods and pay the grid storage fee of $0.05/ kWh. The latter could eliminate battery storage costs, if the community did not want back up storage. However this would not allow the community to be self-sufficient during a loss of power from the grid.

If the community were to take complete ownership of the project, and pursue this option, they would have to seek alternative financing options and identify key leaders in the community who would assist in the deployment of the project. Due to the high cost of the projects, high interest rates, lack of government subsidies, lack of FIT policy, the economic level of the communities and lack of assistance from external organizations that can provide legal and financial assistance, developing a microgrid without altering the above factors, is not advised.

5.2.3. CE partnered with the local distribution Company

Under Law 8345 distribution companies are allowed to generate their own energy. Therefore, any excess energy generated from the community microgrid could be sold to local distribution company (LDC), which in this case is ICE. The price per kWh would be negotiated with the LDC. That information was not available for this study.

Another option for the community could be to install a small solar PV system in a central location that would be connected to the grid only, not through a micro grid, and negotiate a tendering contract with the distribution company. Community members could have the option of purchasing shares in the project, dependent on their financial flexibility, and obtain profits from the project at the end of year, dependent on the tendering contract negotiated with their LDC. The profits from this project could be given back to the community members, and a percentage could be kept in a community bond, and reinvested into further infrastructure developments in the community. However, since a CE partnership with an LDC or electricity cooperative has never been done before in Costa Rica, it is not advised for this community to pursue this model.

The community would face similar payback issues to the micro grid proposal above. The lack of experience, supporting policy framework and financial factors do not make this model viable.

5.2.4. CP Model like ASADAS

The last proposed model for CE in the communities would be the best option available. However, it too requires a shift in Costa Rica's policy framework. Community energy could be developed with the use of a pre-existing cooperative model in Costa Rica, known as Association of Aquatics and Sewage Management (ASADAS). ASADAS is responsible for the administration of communal water and sewage systems in rural communities of Costa Rica (A& A Consultores, 2008). The national water authority, the Institute of Aqueducts and Sewers (Aya) constitutes and administers ASADAS. It assists in the maintenance and development of aqueducts including drinking water and sewage systems (Monge, Paz & Ovares, 2013). ASADAS are formed by local residents of a community who provide the local materials, labour and administration. This model has proven to be successful as it supplies water to approximately 30% of the population through about 1500 organizations (Monge, Paz & Ovares, 2013). This model could be used to develop and maintain energy projects, in the same manner as water and sewage projects currently are managed.

An ASADAS for energy could be possible with the development of a similar organizing body. This could be an Association for Energy Development (AED). Just as local involvement and local resources are used in the ASADAS model, an AED model would have similar structural components. Additionally, just as AyA assists and administers ASADAS, there would need to be an organization that provide the same for AED. Possible organizations could be ARESEP (who already administers and regulates the energy market in the country), or a new body that administers this role.

This model would help in lowering the initial costs of renewable energy projects for communities by offering financial assistance that could be dispensed through grants, as well as administrative and legal expertise. If AED and ARESEP could provide solar PV projects at subsidized rates to communities, it would give communities the opportunity to generate profits much sooner than the simulated models projected. Here the profits generated could be reinvested into the local community, as the 'Commons Good Danish model' aims to do. This model of community energy would be effective because it follows a pre-existing structure. Administrative assistance would be available, lessening the burden on local members who may not be as confident as others. This model would minimize financial risks, as it would not be funded solely by the community, but rather through internal and external government assistance. The model does require a policy shift in Costa Rica's energy framework. It requires the development of an energy association, outside of ARESEP. It requires ARESEP to regulate and administer this new energy association, and it requires subsidies for renewable energy projects. Without these alterations, CE cannot be successful in Costa Rica.

5.3 Organizations available for support

Currently, community energy is not viable in Costa Rica. As the research has shown, creating CE is extremely difficult without financial assistance and a lack of FIT policy. Nonetheless, there are many alternative energy advocacy groups and organizations exploring the implementation of renewable energy systems. These organizations could have large impacts on the development of the renewable energy sector in Costa Rica, and may even stimulate CE in some way.

5.3.1. The Costa Rican Association of Solar Energy (ACESolar)

This is an association focused on promoting solar energy in Costa Rica through research and advocacy. Their focus is to engage with the general public on the benefits of solar energy and support the introduction of solar technologies in the business sector (ACESolar, 2016).

5.3.2. Ad Astra Rocket Company (Ad Astra/ AARC)

Ad Astra is a technology leading company dedicated to the development of plasma rocket propulsion. In addition, the company is researching the further development of renewable energy infrastructure in Costa Rica by offering wind power energy storage and waste to energy conversion solutions (Ad Astra, 2015). On March 18th, 2016, Ad Astra completed a 76 kW solar powered project, and now gets 100% of its energy on site, making it the largest ground mounted private solar installation in the country (Ad Astra, 2016).

5.3.3.Technological University of Cost Rica (TEC) University: Laboratorio de Sistemas Electronicos para la Sostenibilidad (SES Lab)

The SES lab is a laboratory in the Technological University of Costa Rica, located in Cartago, Costa Rica. The SES lab is a segment of the School of Engineering and Electronics, focused on researching electric systems for sustainability. The focus of this lab is to conduct research on solar PV systems and to develop electronic systems that enhance the sustainability of physical systems (Guzman, 2012). Future plans of the SES Lab involve the development of the first hands on training program for solar installation (Meza, 2016).

5.3.4. Earth University

Earth University in Costa Rica has a partnership with the Renewables Academy in Berlin, Germany to train and teach on renewable energy technologies (Earth University, n.d). The department provides education and training to students on renewable technologies with the adaptation of small-scale applications for communities *(Ibid)*. It is the first Renewable Energy Laboratory of its kind in Central America *(Ibid)*

5.3.5. The Urban Sustainability Center- Centro Para La Sostenibilidad Urbana (CPSU)

This is an NGO founded in Costa Rica that aims to transform communities towards more sustainable and resilient practices, increasing the quality of life for its habitants. CPSU focuses on: energy, waste, sustainable transportation, water, biodiversity, sustainable food systems and equity and local economy (CPSU, 2016).

5.3.6. ESCOIA

This is a consulting firm that provides advice on developing projects in sustainable energy, industrial solutions, bio-resources and the environment in Central America (CPSU, 2016).

5.4. Financing

Financing tends to be one of the biggest obstacles in the development of renewable energy projects. There are three different methods of financing available, aside from receiving funding through national and international organizations like The World Bank or USAID, a US foreign assistant program that supports the private development of clean energy in the Caribbean and Central America (USAID, 2015). Although there are some funding opportunities available, there is no guarantee that projects will be funded. There is a lack of government assistance programs in Costa Rica for the development of renewable energy. The financing options below would not be suited for the case community as they all require customers to have credit, and may require collateral, something that the community members may not have access to. These financing options may be best suited for individual customers, or those communities with access to the required resources. Additionally, having access to a lease agreement alone will not make the project financially feasible. A return on every kW fed into the grid is needed.

5.4.1. Leasing through banks

Costa Rica's banking system is offering financing options for those interested in developing a renewable energy projects, but cannot produce the hefty upfront costs associated with them. A financing option for renewable energy projects for companies interested in financing offered by the Bank of Costa Rica outlines the terms below:

Terms:
100% Financing
10 Year term
7.9% interest on US dollar, 12.45% on colons
Provides: Warranty by Garment Aval Equipment and CABEI, legal expenses (1% per project) and disbursement fee of 1%.
A grace period of the first 6 months that are interest free
No premium or mortgages required

Requirements:
Incorporation of the company
Copies of certificate of legal representative and shareholders of the company (partners with 10% or more of shares)
Copy of legal identification or registration status
Financial statements signed by the legal representative and counter the fiscal year closing September 2012, 2013, 2014, and September 2015 with notes and detailed inventory, accounts payable and accounts receivable
Projected cash flow to the loan
Feasibility study

Solar companies like *Purasol* and *Costa Rica Solar Solutions* also offer financing for residential or commercial renewable energy projects through national banks such as Promerica, and other national banks. *Costa Rica Solar Solutions* offers financing with a 20% down, on a 7 year term with an annual interest of 8% percent (Costa Rica Solar Solutions, 2016).

5.4.2. Leasing through private investors

Financing through private investors could show similar returns, dependent on the conditions negotiated. However, acquiring loans through private investors could pose risks for communities or individuals as outside interests may influence factors, and financing alone will not be enough to provide an attractive simple payback for the communities.

6. Conclusion & Recommendations

Community energy aims to supply a decentralized source of energy for communities, while at the same time meeting local economic, social and environmental needs. The European model demonstrated the success of community energy projects. Community energy offers a way to transform the “not in my backyard” movements to “please on our land” movements. Community energy offers the opportunity for members to produce non-conventional, reliable, resilient and local energy, while at the same time contributing to the development of social relations within the community. Community energy also offers the opportunity for communities to function through democratic methods, and practice participatory engagement from within.

Costa Rica, has managed to electrify almost 100 % of its population, without the practice of distributed generation, but rather through an energy sector that is dominated by large hydro production (80%). An energy market like Costa Rica’s could be impacted by climate change causing unpredictable rainfall, and droughts in some cases. Climate change impacts pose serious threats to its current energy market, calling for an expansion towards other sources of energy. In addition, Costa Rica’s energy market is monopolized by state owned companies, and its laws allow for very little room for private generation to occur. State owned companies not only dominate energy generation, but also distribution of energy. Approximately 80% of the country’s territory is covered by state owned companies like ICE. Additionally, ICE controls 100% of the transmission grid, regulating the transmission of energy from generation to distribution. With an increasing GDP and population growth, the country will have to expand its installed capacity to 3.9 GW by 2021 in order to meet its growing energy demand. It must also explore distributed generation systems and long-term energy efficiency programs.

Costa Rica has set an ambitious target to be the first country in the world to be carbon neutral by 2021. Its Expansion Plan aims to continue to develop its energy market through hydro plants, despite their social and environmental impacts. Currently, there are no supporting policies for community energy. However, its Public Service Regulating Authority, ARSEP, has introduced a new net metering program that would allow customers to store excess energy on the grid for a small fee. The aim of the new net metering program is to expand self-generation and meet the growing demands for renewable energy in the country. This policy will also stimulate the current small solar energy market in the country.

Costa Rica's role in the Pan American energy market is also a factor in its need to expand into other energy sources like wind and solar. The country is dependent on the import of energy during the dry and hot season, when hydro generation is low. An effective response to this can be provided through community energy projects. However, there are some obstacles in relation to the political structure of a co-owned project, as well as financing issues and a lack of supporting government policies. Community energy could be beneficial for rural communities that are situated on the peripheries of urban centers, and are experiencing slow economic development. These are the same communities that face the most challenges in developing community energy projects. The situation in the ASBC community is a prime example of this.

The case communities would benefit from community energy, as they would have the opportunity to meet their local social, economic and environmental needs through community energy. Research presented by Pembina Institute and Greenpeace outlines the importance of community engagement/ownership and the involvement of external bodies as essential components of community energy success. However, the lack of financing options and an all but obsolete government supportive policy pose as obstacles to the success of community energy in rural Costa Rica. In order to have successful community energy projects, policies like a FIT need to be adopted so renewable energy generators can attain an attractive return on investment. Without concrete energy policies that provide incentives for generating renewable energy, it will be impossible for communities to acquire an appropriate return on investment from the energy system. The success of community energy projects in European states such as Germany and Demark can both be linked to "macro-level institutional factors such as feed-in tariff policies" (Department of Energy and Climate Change, 2014). The Danish model of community energy would not be successful without the existence of a FIT policy. The current renewable energy policy framework in Costa Rica is embryonic, and is based on traditional ownership models that do not allow for private investment and ownership. Although, a new net metering framework has been introduced, it stimulates the development of individual generation systems, while discounting community owned ones.

This paper outlines four community energy models that could work in the ASBC. The first one is an *off grid model*, which is best suited remote communities. It would either operate through a government funded program, or through high personal or private funding mechanisms neither of which would be feasible in the case communities.

A second community energy model suggested a *micro grid*. A micro grid community energy model would require the case communities to be internally connected to one grid that would then be connected to the external electricity grid. This model would require large investments into upgrading the electrical infrastructure of the community. Due to the low energy consumption of each household in the community (average in Santa Elena: 188 kWh/month, Quizarra: 156 kWh/month), installing a renewable energy project would not help in lowering energy costs, as the average household already receives a subsidized electricity rate from its

LDC, ICE. Even though Law 7200 supports private generation of energy, there is no legal framework for what a tendering contract would look like for the generator, allowing for prices to fluctuate and not guaranteeing the generator a price per kWh generated. This model would not be suitable for the case communities, as it would not provide an attractive guaranteed tariff for power generated and sold to ICE, disallowing private profits to be generated and reinvested back into the community.

A third model proposed was through a *partnership with a local distribution company*. As Law 8345 allows distribution companies to generate their own energy, the community could act as a generator for the LDC, while receiving compensation for energy generated. However, there are no laws in Costa Rica that stipulate the price an LDC would pay a generator. This would have to be negotiated. This model could generate profits for the community. However, the amount and duration of profit generation is unknown, making this model unsuitable for the community.

The last model proposed was creating a *CP model like ASADAS* through the development of an AED, association of energy development. This model would follow a similar framework to the pre-existing water management model of ASADAS. Community energy through this model may the best option for the case community, as well as other communities looking at developing energy projects. This model suggests the development of an external body that would assist in administrative duties, and financial inequalities when deploying a community energy model. Additionally, this model requires the involvement of ARESEP to govern the energy market, demanding a shift in Costa Rica's energy policy framework.

After careful analysis, the paper concludes that the fourth model, *CP model like ASADAS* would be the best option for a successful community energy project in Costa Rica. However, this model requires a change in the current policy framework. The current policy framework in Costa Rica and the ASBC, is insufficient to support environment for community energy. If community energy were to be seriously considered, the best model to adopt would be one similar to ASADAS. However this also requires change in financial incentives, and governing bodies. In addition to creating a more competitive policy framework for private generation, it is recommended that alternative avenues be considered in reducing the cost of electricity for the communities of the ASBC and other communities in the country.

Recommendations:

1. Appropriate supporting government policies (FIT)

FIT policies are essential tools for enabling community level proponents to be involved in renewable energy projects. Adopting a FIT policy in Costa Rica could help communities to become involved in energy projects, by providing incentives for generating electricity. FITs provide an avenue for communities to reinvest profits into developing the community further, and have proven to be successful in the deployment of renewable energy at the community level in the global context. A FIT policy will provide incentive for communities to shift towards renewable energy systems. Lastly, a FIT policy will contribute towards a greater source for private generation and diversify the energy mix of the country. In partnership with FIT policies, better access to financial mechanisms that would assist in the deployment of renewable energy projects are recommended.

2. The development of Association of Energy Development (AED)

Creating a governing for the development of distributed energy systems in Costa Rica would provide much needed administrative and financial support. It is recommended that an

Association of Energy Development (AED), similar to the organizing body, ASADAS be created. An AED would be able to provide resources and access to legal expertise that would otherwise be inaccessible to energy generators. An AED could act as a liaison between community groups and government officials providing access to subsidies or other financial incentives for CE. The development of this association would lessen the burden for community groups, while increasing the effectiveness of a CE project.

3. Education on Energy Efficiency

Increased awareness and educational programs could be used as tools to reducing energy consumption in the communities. Educating the local community members on the benefits of energy efficient technologies and encouraging behavioral changes could assist in lowering household utility bills. Technologies such as LED light bulbs, will assist in dramatically lowering already low electricity bills of the households surveyed. The study found that many households were using 100-watt bulbs before 7-10 watt LED bulbs were given to the homes. This shift in using energy efficient light bulbs will significantly reduce utility bills of these households. Continued education and support programs that educate the public on ways they can save energy in their homes should be developed. The benefits of energy efficient appliances should also be considered. The largest energy consumer in most homes is the refrigerator. Educating the community on the long term benefits of purchasing an energy efficient fridge could also significantly lower utility bills. Pairing energy efficiency technologies with education provides an opportunity for negawatts to occur, which is the first step of developing a community energy plan.

It is also recommended that energy education and energy efficiency be a topic of discussion during the annual Alexander Skutch Festival in the spring, as well at Casa Azul, York University's library in the corridor. On a national level, energy efficiency and demand management should be a priority in the country's energy framework moving forward.

Further Study

Further study should be done on how community members can use biogas in their households as a source of energy. Since the community is largely based on agriculture and has access to livestock, it would be ideal for biogas production. Research into developing a simple biogas project that community members can construct and install in their own homes would benefit the community greatly taking advantage of a pre-existing energy source. On the other hand, a centralized biogas facility may be more beneficial for the community than individual household constructions. Further research into determining which method is more suitable needs to be conducted. Demonstrations of this model could be delivered at the annual Alexander Skutch Festival and Casa Azul. Lastly, it would be interesting to see the difference in utility bills of the households that were given LED light bulbs in March 2016.

CE can be a useful tool for community development; however, political and financial incentives must also be made available for the deployment of it. At this moment, the ASBC community is not a suitable candidate for CE to occur.

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Appendix

Appendix 1: Historical energy generation in Costa Rica, dominated by hydro since the 80's (ICE, 2015).

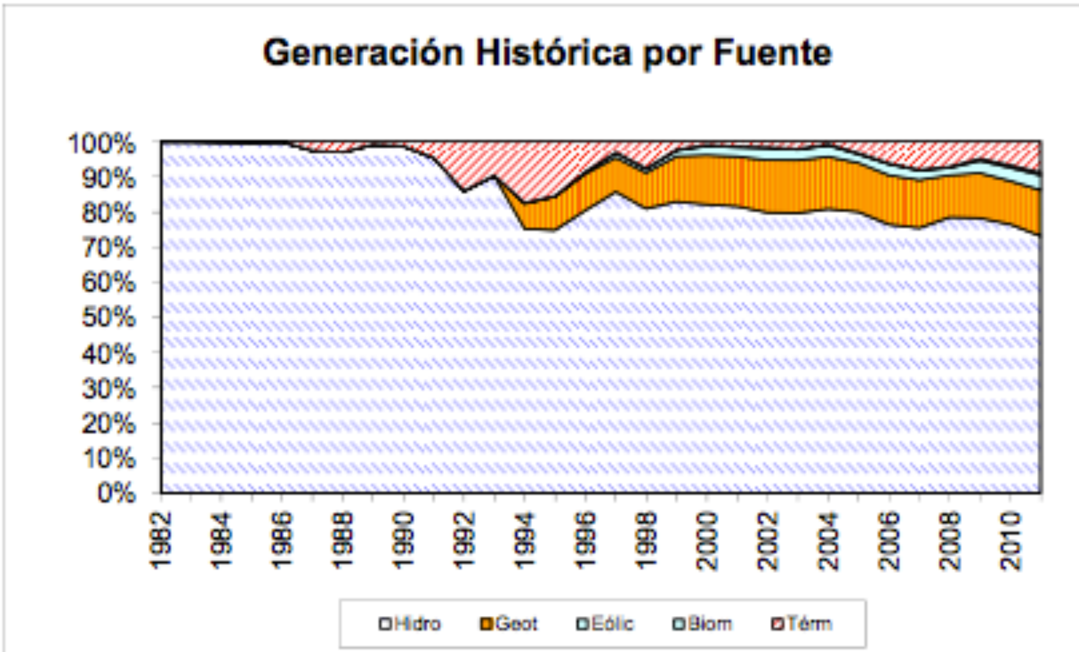
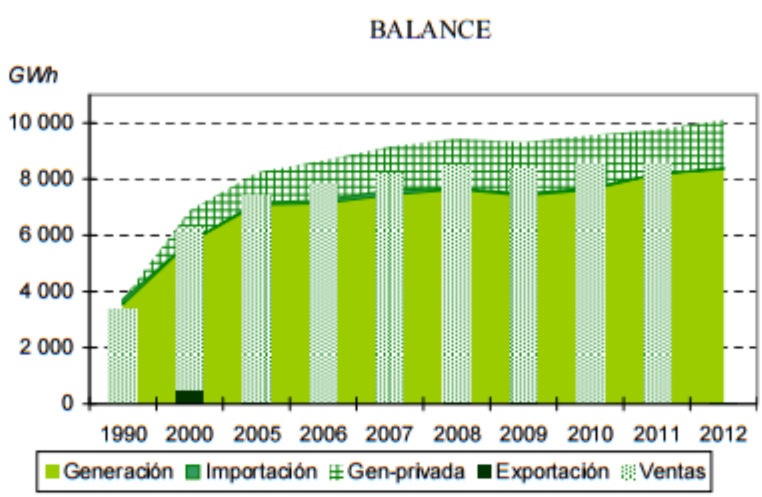
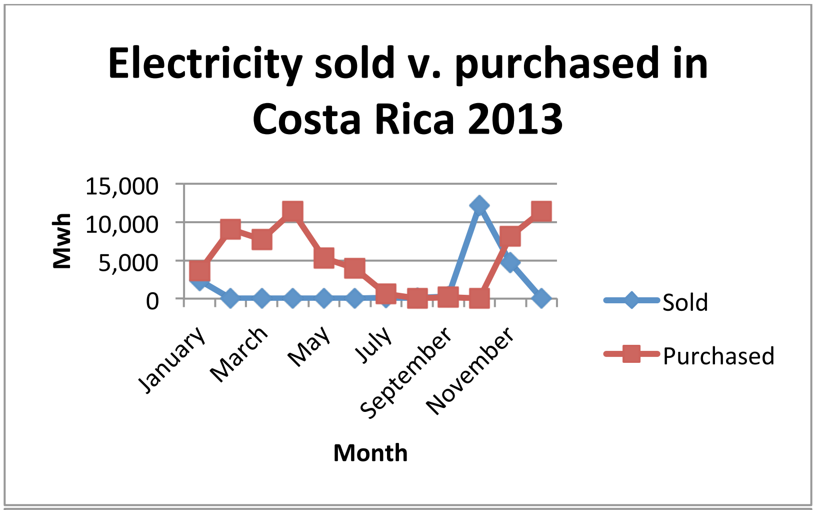


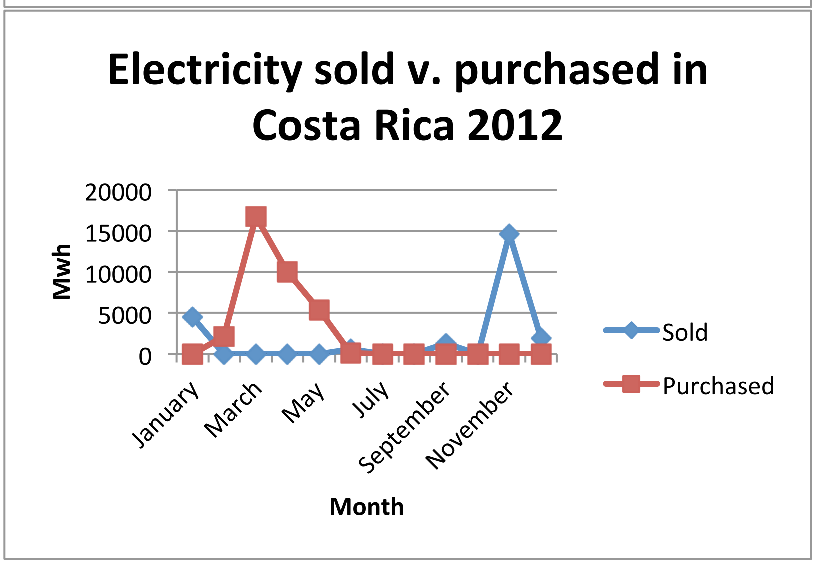
Figura 4-2 Generación histórica por fuente

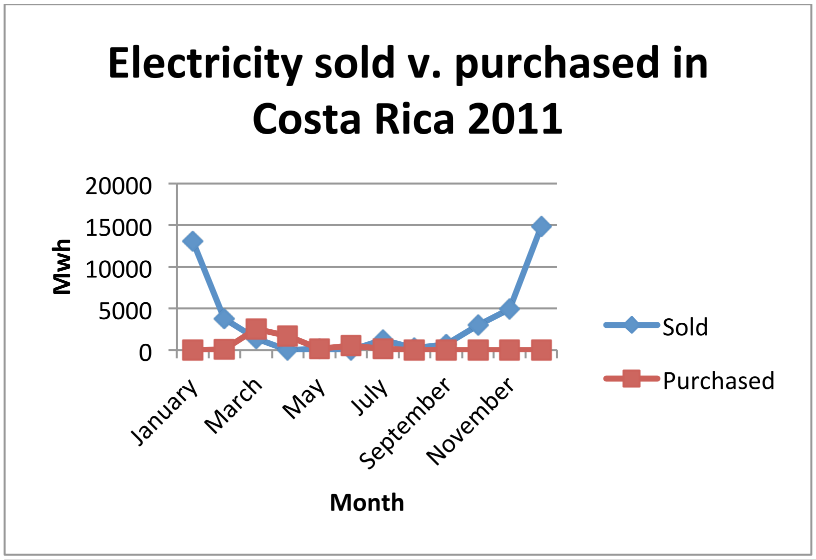
Appendix 2: Historical trends of electricity import versus export in Central America (Cepal, 2012).

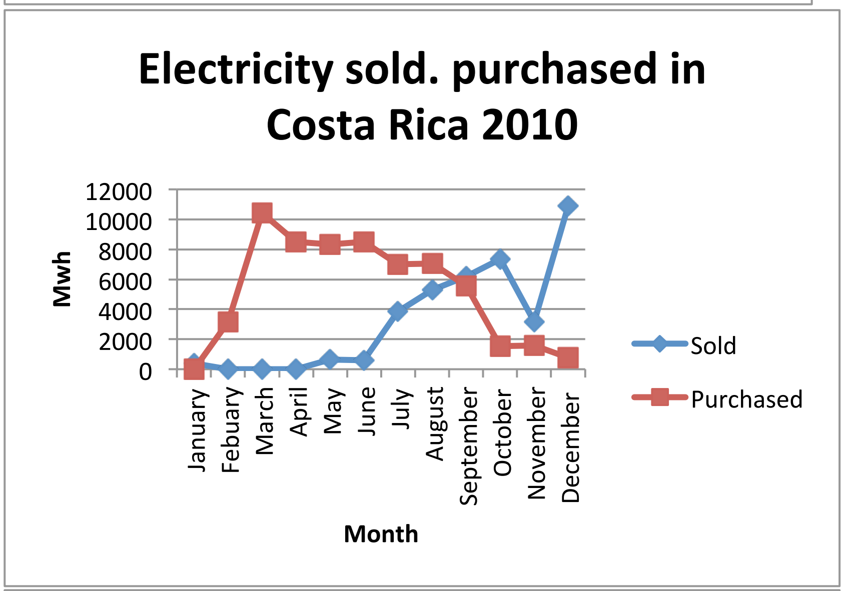


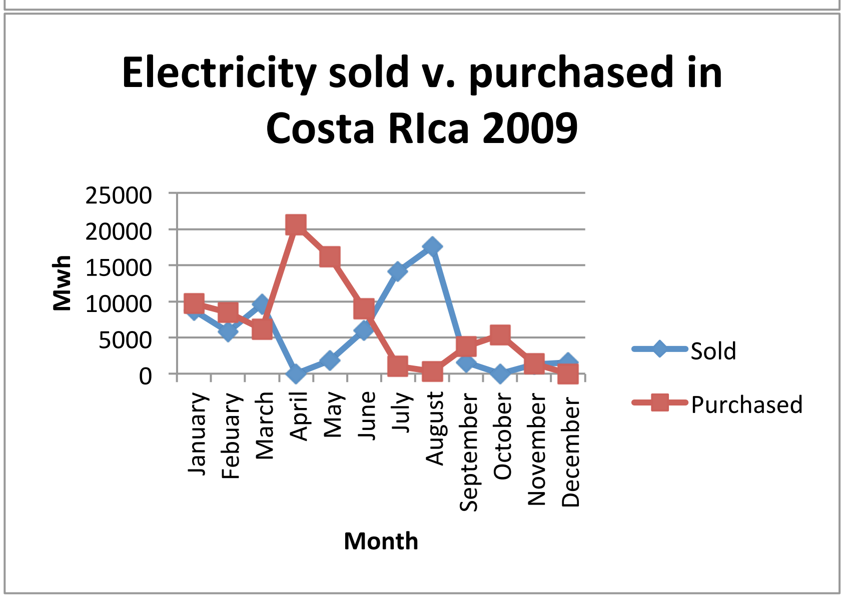
Appendix 3: Historical trends of electricity import versus export in Costa Rica per month (Cepal 2014, 2013, 2012, 2011, 2010).






Electricity sold v. purchased in Costa Rica 2011
20000
15000
10000
5000
0
Mwh
January
March
May
July
September
November
Month
Sold
Purchased

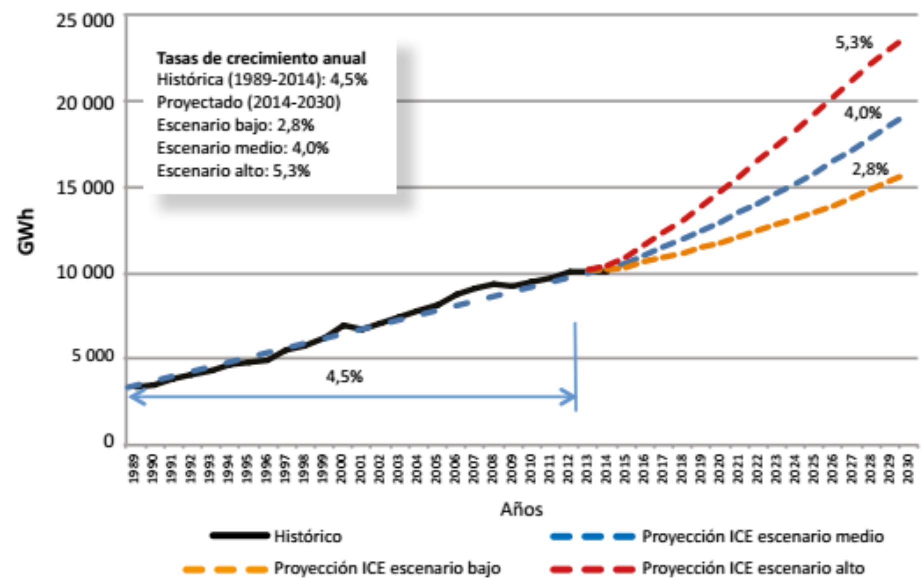

Electricity sold. purchased in Costa Rica 2010
12000
10000
8000
6000
4000
2000
0
Mwh
January
Febuary
March
April
May
June
July
August
September
October
November
December
Month
Sold
Purchased


Electricity sold v. purchased in Costa RIca 2009
25000
20000
15000
10000
5000
0
Mwh
January
Febuary
March
April
May
June
July
August
September
October
November
December
Month
Sold
Purchased

Appendix 4: Projection of energy demand in Costa Rica, through a low (yellow), medium (blue), and high (red) scenario (MINAE, Energy Policy, 2015).

Gráfico 12.

Costa Rica: evolución de la generación de electricidad histórica (1989-2014) y proyectada por el ICE (2015-2030).



Appendix 5: Future plans set out by ICE for each energy source (ICE, 2015).

Tabla 14-1 Composición por fuente de la nueva capacidad

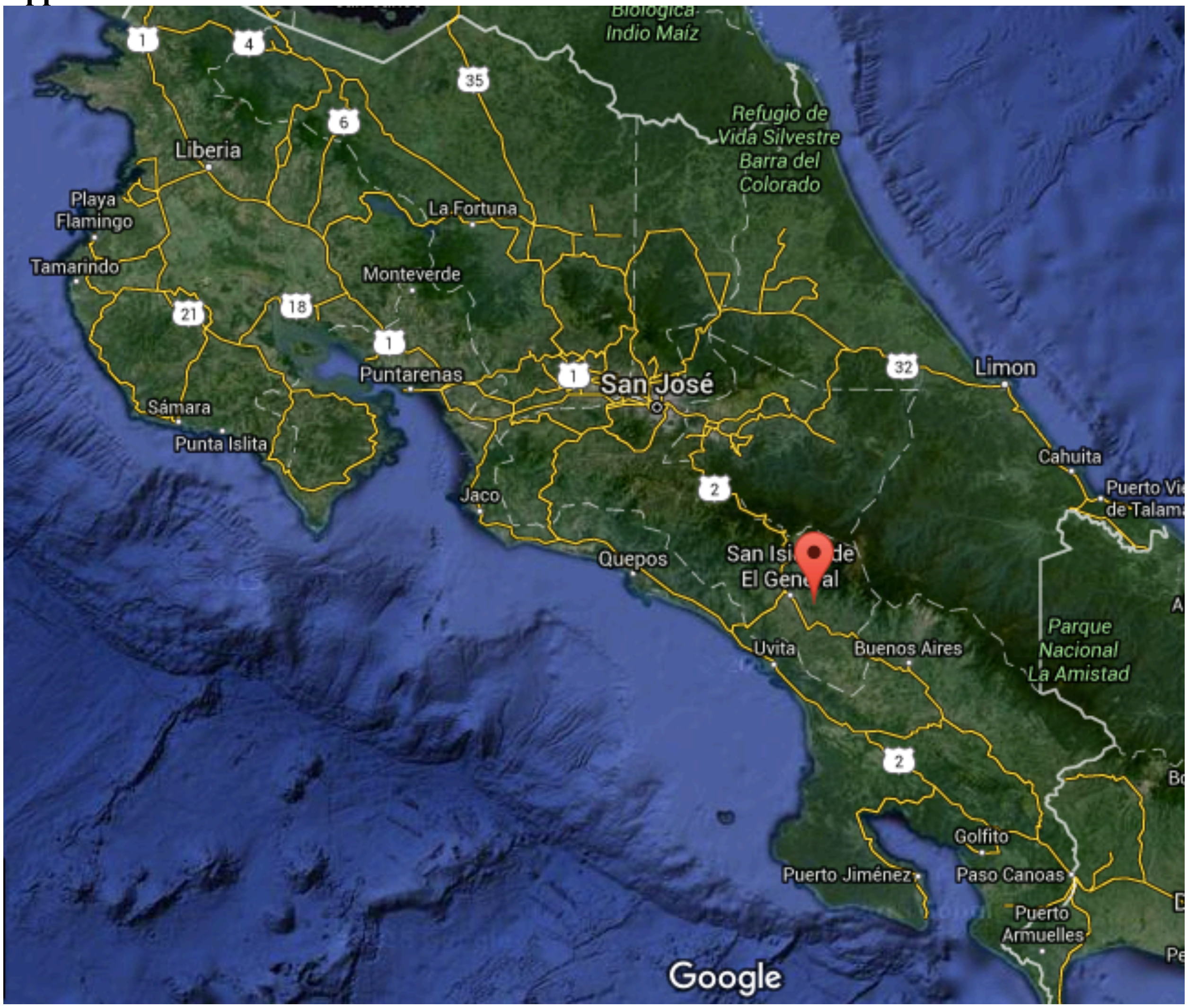
Porcentaje de instalación por fuente					
Año	Hidro	Geot	Eól+Biom	Térm	Total
2011	65%	8%	6%	21%	100%
2012	66%	7%	8%	19%	100%
2013	67%	7%	7%	19%	100%
2014	72%	7%	7%	14%	100%
2015	67%	6%	8%	18%	100%
2016	70%	6%	7%	17%	100%
2017	70%	6%	7%	17%	100%
2018	69%	7%	7%	17%	100%
2019	74%	7%	6%	14%	100%
2020	72%	7%	8%	13%	100%
2021	72%	7%	8%	13%	100%
2022	72%	7%	8%	13%	100%
2023	72%	7%	8%	13%	100%
2024	72%	7%	8%	13%	100%

Appendix 6: List of Hydro power plants in Costa Rica (ICE Expansion Plan, 2013 & Global Energy Observatory)

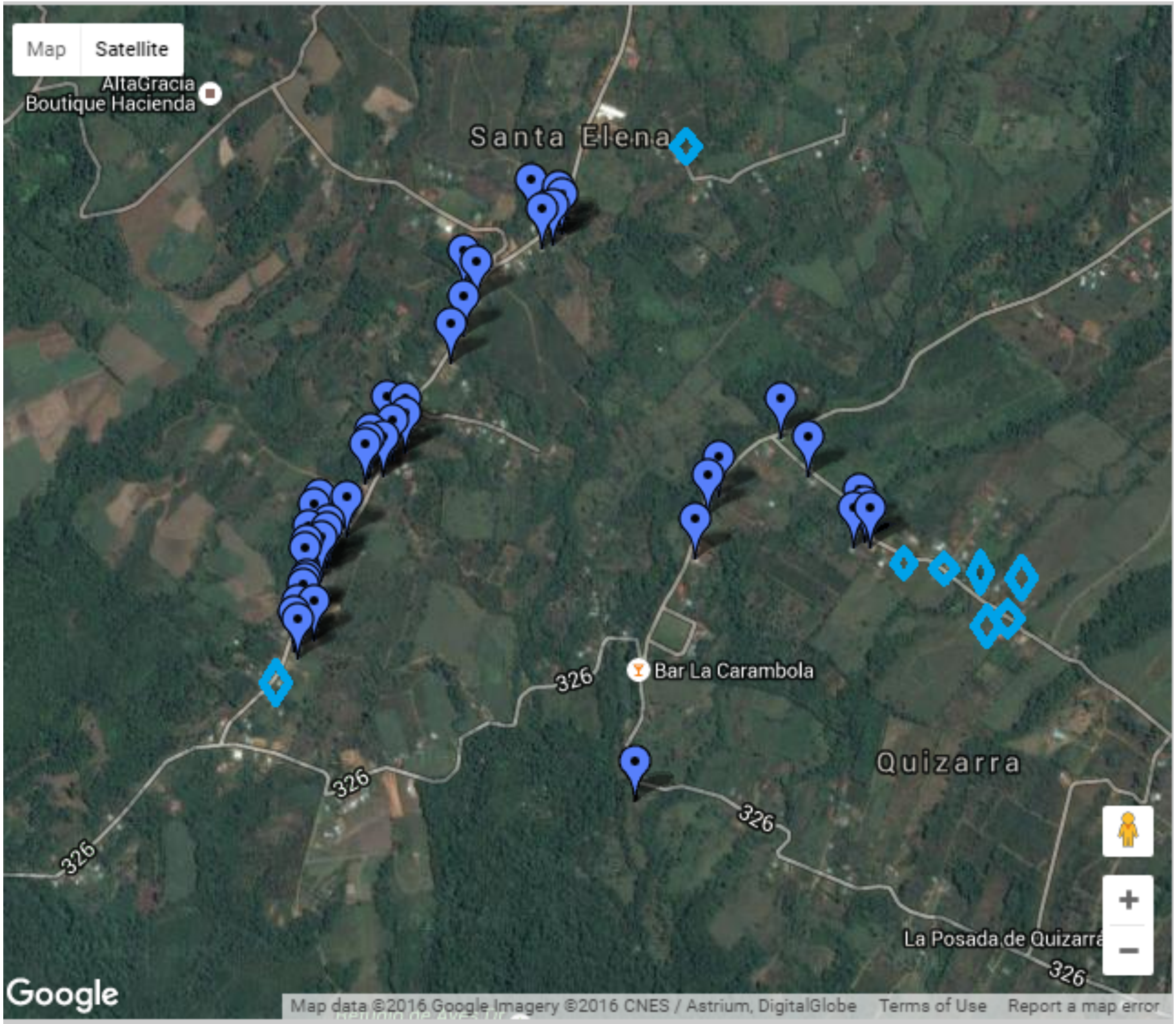
Name	Longitude	Latitude	City	Capacity MW
Alberto Echandi Hydroelectric Station Costa Rica	-84.4383	10.39158	Alajuela	4.7
Angostura Hydroelectric Power Station Costa Rica	-83.6424	9.92205	Cartago	180
Anonos	-84.1002	9.940202	San Jose	0.6
Arenal Hydroelectric Power Plant Costa Rica	-84.9989	10.4755	Guanacaste	157
Belen	-84.1002	9.940202	San Jose	10.5
Brasil	-84.1002	9.940202	San Jose	3
Birris 1 Hydroelectric Power Plant Costa Rica	-83.7771	9.866	Cartago	18
Birris #2	-83.6774	9.75396	Cartago	2
Birris 3 Hydroelectric Power Plant Costa Rica	-83.7869	9.8944	Cartago	4
Cachi Hydroelectric Power Station Costa Rica	-83.8038	9.84069	Cartago	109
Cacao	-84.4383	10.39158	Alajuela	0.67
Canalete				66
Carrillos	-84.4383	10.39158	Alajuela	2
Chocosuelas	-84.4383	10.39158	Alajuela	28
CNFL Virilla				56
Corobici (Miguel Pablo Dengo) Hydroelectric Power Plant Costa Rica	-85.0763	10.4695	Guanacaste	174
Cote				13
Daniel Gutierrez				19
Don Pedro Hydroelectric Power Plant Costa Rica	-84.172	10.313	Heredia	14
Dona Julia				16
Electriona	-84.1002	9.940202	San Jose	6
La Garita Hydroelectic Power Plant Costa Rica	-84.339	9.9853	Alajuela	30
General				39
Gen Prin Hidro1				39
Gen Priv Hidro 2				41
Gen Priv Hidro 3				11
Ice Menores				5
JASEC Menores				20
La Joya Hydroelectric Power Station Costa Rica	-83.685	9.8546	Heredia	50
Los Lotes Hydroelectric Power Plant Costa Rica	-83.6774	9.75396	Cartago	0.375

Los Negros				17
Nuestro Amo	-84.4383	10.39158	Alajuela	8
Penas Blancas Hydroelectric Power Plant Costa Rica	-84.4383	10.39158	Alajuela	38
Pirris Hydroelectric Power Station Costa Rica	-84.198	9.6314	San Jose	140
Pocosol				26
Puerto Escondido	-83.6774	9.75396	Cartago	0.2
Rio Macho Hydroelectic Power Plant Costa Rica	-83.8414	9.7757	Cartago	120
Rio Segundo	-84.4383	10.39158	Alajuela	0.25
Rio Segundo #2	-84.4383	10.39158	Alajuela	0.5
Rio Volcan Hydroelectric Plant Costa Rica	-84.172	10.313	Heredia	17
San Lorenzo				15
Sandillal Hydroelectric Power Plant Costa Rica	-85.1034	10.4645	Guanacaste	33
Toro I Hydroelectric Station Costa Rica	-84.3056	10.2204	Alajuela	23
Toro II Hydroelectric Power Station Costa Rica	-84.3058	10.222	Alajuela	65.2
Ventanas-Garita Hydroelectric Power Station Costa Rica	-84.3506	9.94425	Alajuela	97.4

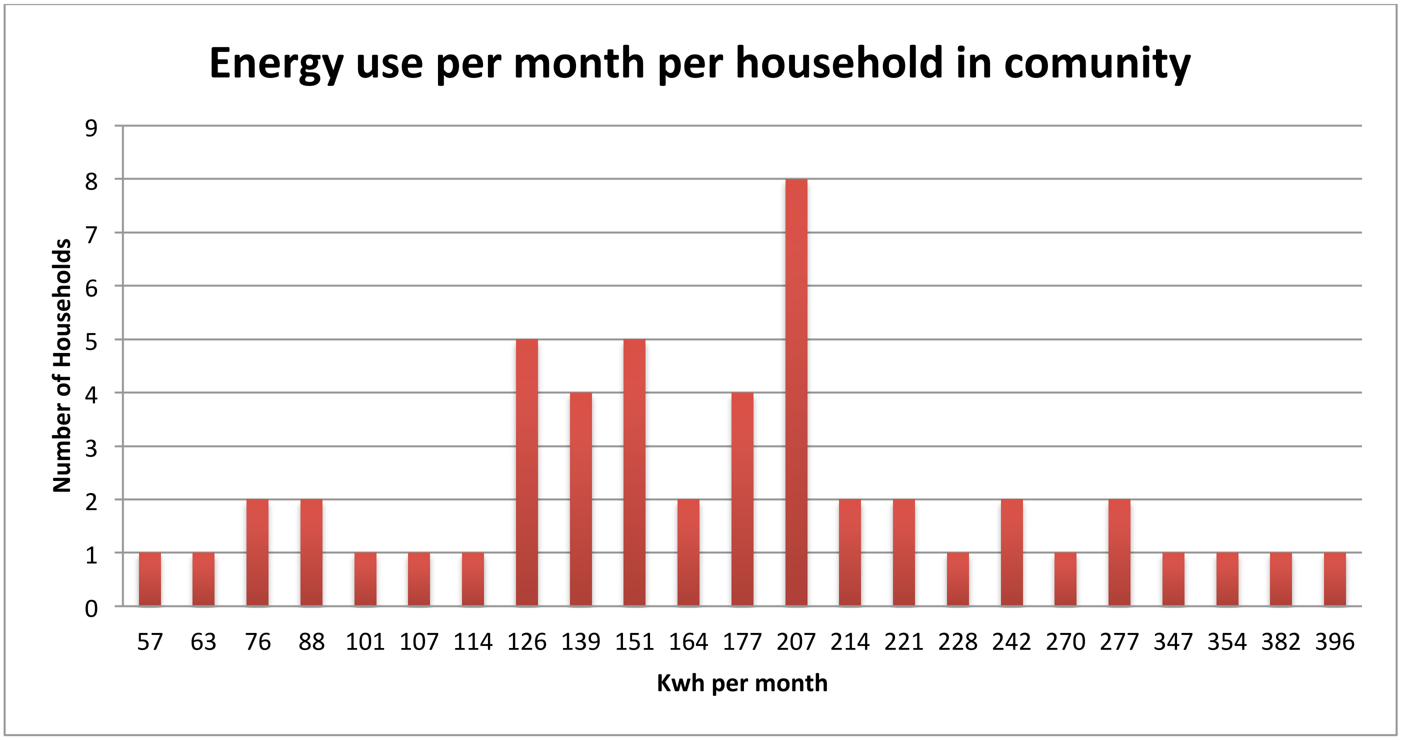
Appendix 7: Location of communities



Appendix 8: Map of households surveyed in each community

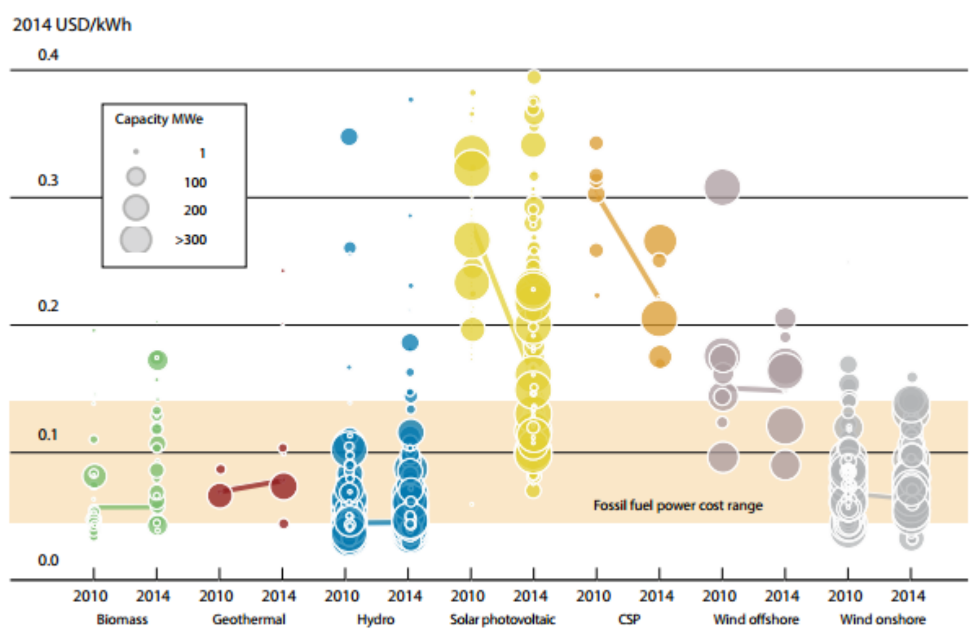


Appendix 9: Energy consumption per household in the two communities.



Appendix 10: Graph of levelised cost of electricity from various energy sources (IRENA, 2015)

FIGURE 2.1: THE LEVELISED COST OF ELECTRICITY FROM UTILITY-SCALE RENEWABLE TECHNOLOGIES, 2010 AND 2014

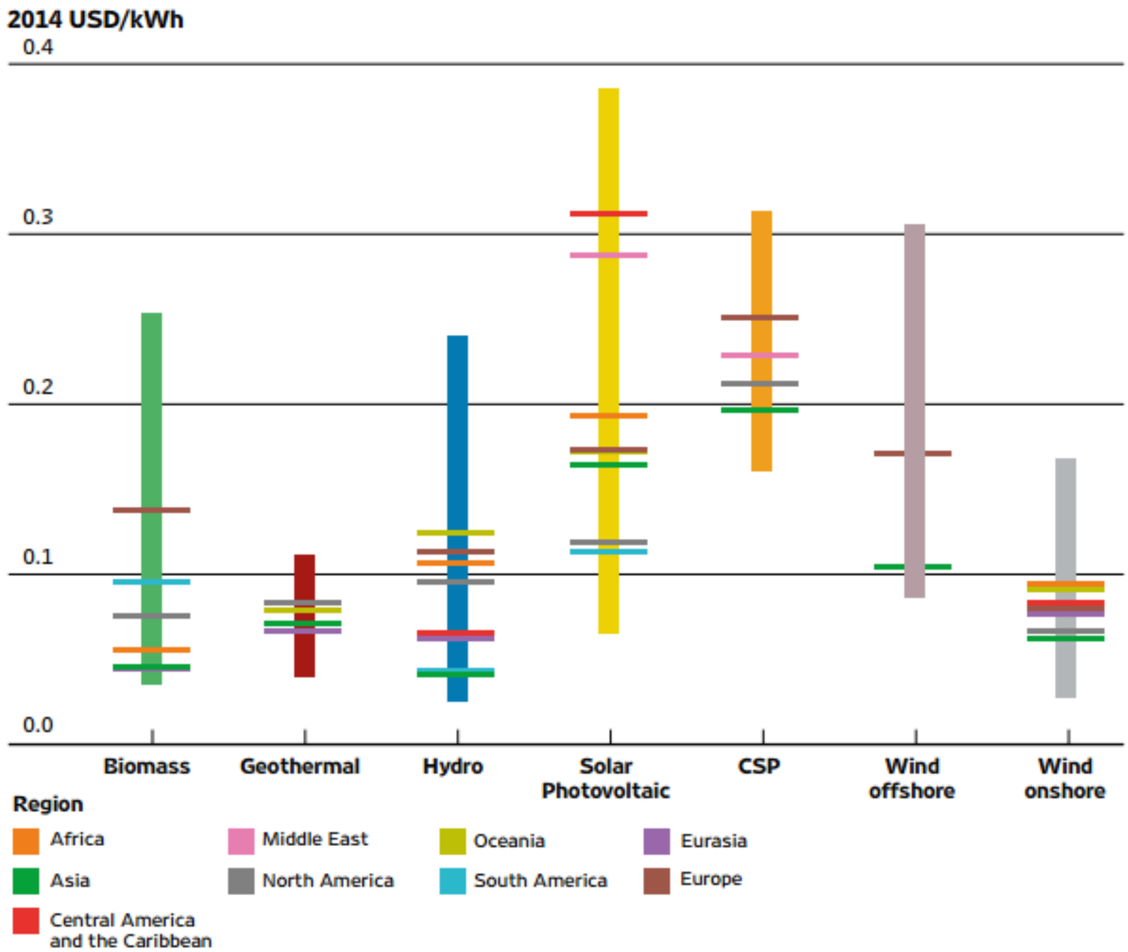


Source: IRENA Renewable Cost Database.

Note: Size of the diameter of the circle represents the size of the project. The centre of each circle is the value for the cost of each project on the Y axis. Real weighted average cost of capital is 7.5% in OECD countries and China; 10% in the rest of the world.

Appendix 11: Graph of levelised cost of electricity ranges by region and technology (IRENA, 2015)

FIGURE 2.3: TYPICAL LEVELISED COST OF ELECTRICITY RANGES AND REGIONAL WEIGHTED AVERAGES BY TECHNOLOGY, 2013/2014



Source: IRENA Renewable Cost Database.

Appendix: 12: RETScreen Feasibility Report Santa Elena

Feasibility report

Community Energy Project Proposal: Santa Elena

68 kW

Power plant - Photovoltaic

Prepared for:

York University: MES

Prepared by:

Nancy Ghuman

Executive summary

This report was prepared using the RETScreen Clean Energy Management Software. The key findings and recommendations of this analysis are presented below:

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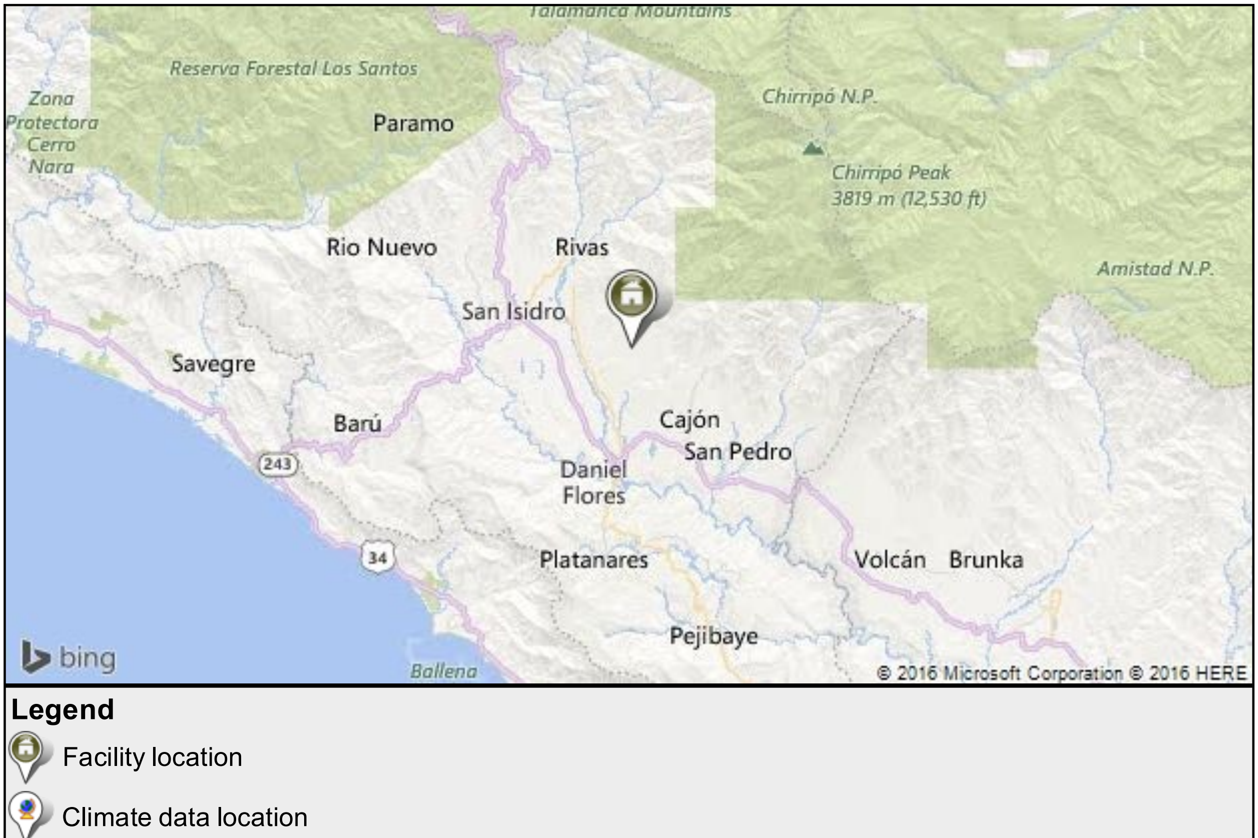
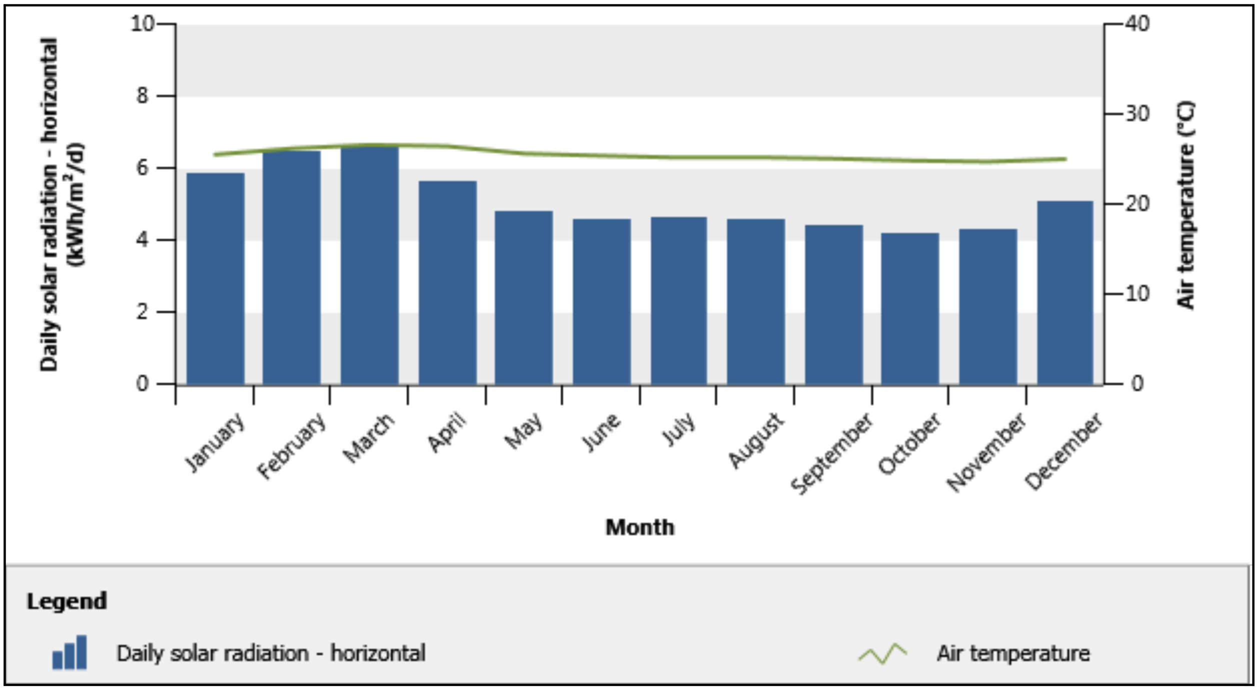
Location | Climate data

Location



	Unit	Climate data location	Facility location
Name		Costa Rica - Guácimo	Costa Rica, Santa Elena
Latitude	˚N	8.95	9.35
Longitude	˚E	-83.12	-83.62
Climate zone		1A - Very hot - Humid	1A - Very hot - Humid
Elevation	m	85.83	766.00

Climate data



Heating design temperature	22.5 °C
Cooling design temperature	29.4 °C
Earth temperature amplitude	4.4 °C

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	25.6	73.2%	91	5.9	98.6	3.8	26.5	0	484
February	26.3	68.4%	61.3	6.5	98.6	3.8	27.5	0	456
March	26.7	67.9%	90.6	6.7	98.5	3.6	28.4	0	517
April	26.5	73.4%	203	5.7	98.5	2.8	28.4	0	496
May	25.7	84%	420	4.8	98.6	2.8	27.4	0	487
June	25.5	85.9%	368	4.6	98.6	2.9	27.1	0	464
July	25.3	85.8%	387	4.6	98.6	3	27	0	473
August	25.3	85.5%	410	4.6	98.6	3.2	26.9	0	474
September	25.2	85.4%	420	4.4	98.6	3.3	26.8	0	455
October	24.9	85.9%	440	4.2	98.6	3.2	26.4	0	463
November	24.8	85.7%	369	4.3	98.5	3.3	26.2	0	444
December	25.1	80.5%	203	5.1	98.6	3.7	26	0	468
Annual	**25.6**	**80.2%**	**3,464**	**5.1**	**98.6**	**3.3**	**27**	**0**	**5,681**