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Renewable Energy in Rural Amazônia: A Case Study of Its Advantages and Limitations in Santo Antônio

Amy Plovnick
SIT Study Abroad

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Amy Plovnick
Washington University in St. Louis
Environmental studies and Political science

Advisor: Leonardo Sena

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Abstract

Isolated renewable energy projects are a promising alternative to diesel power for providing electricity in rural communities not connected to the conventional electricity transmission grid. However, there have been a limited number of such projects in rural Amazônia, and they often face obstacles that limit their sustainability. The objective of this study is to evaluate the environmental, social and economic impact of isolated renewable energy projects through a case study of a small-scale biomass and solar energy electrification project in the community of Santo Antônio, Pará. It will also evaluate the limitations to implementing and sustaining isolated renewable energy projects and discuss policy options for increasing the number and success of such projects in rural Amazônia. Through interviews with residents of Santo Antônio and professionals involved with the implementation of the electrification project, it was determined that the electrification project in Santo Antônio has the potential to help the community socially and economically. It will also likely provide energy to the community for many years due to the community's strong organization and leadership and plan for maintaining the equipment. In addition, these energy sources have a minimal environmental impact, especially when compared with diesel fuel. Challenges that this and other isolated renewable energy projects face include obtaining funding for the projects, maintaining the systems, and developing productive uses for electricity. Government policies and programs that provide funding and regulation for isolated systems could help overcome these challenges and increase the number of renewable energy projects in rural communities.

Resumo

Os projetos isolados de energia renovável são uma alternativa promissora a energia diesel, por fornecer eletricidade em comunidades rurais que não são conectados a rede convencional de transmissão de eletricidade. Entretanto, existem poucos desses projetos na Amazônia rural, e muitas vezes encontram obstáculos que limita sua sustentabilidade. O objetivo deste estudo é avaliar os impactos ambientais, sociais, e econômicos dos projetos isolados de energia renovável, por um estudo de caso de um pequeno projeto de eletrificação de energia de biomassa e energia solar na comunidade de Santo Antônio, Pará. Também, o estudo avaliará as limitações de implementar e sustentar projetos isolados de energia renovável, e discutir opções de políticas para aumentar o número e sucesso desses projetos na Amazônia rural. Por meio de entrevistas dos moradores de Santo Antônio e profissionais envolvidos com o implementação do projeto de eletrificação, foi determinada que o projeto de eletrificação em Santo Antônio tem o potencial para ajudar socialmente e economicamente o comunidade. Também, provavelmente fornecerá energia à comunidade por muitos anos, devido à forte organização e liderança da comunidade e ao plano para manter os equipamentos. Estas fontes de energia tem mínimos impactos ambientais, especialmente quando comparadas ao combustível diesel. Desafios que este projeto e outros projetos isolados de energia renovável encontram incluem obter financiamento para os projetos, manter os sistemas, e desenvolver usos produtivos para a eletricidade. Políticas públicas e programas do governo que forneçam o financiamento e a regulação por sistemas isolados, podem ajudar a superar estes desafios e aumentar o número de projetos de energia renovável em comunidades rurais.

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Introduction

Electricity demand in Brazil is expected to rise 5% a year over the next 10 years due to an increase in industry and consumer use. To meet this demand, the country will need to double its electricity capacity by 2020 (World Wildlife Fund, 2010). Much of this increase in demand is coming from rural areas, in part because the government *Luz Para Todos* (Light for All) program gives utilities access to federal money to bring electricity to people previously without access (Zerriffi, 2004). Despite this increase in demand, rural communities in the Amazon region often have limited access to electricity. In 2004, 21% of the people in the Amazonian state of Pará didn’t have access to the electricity grid; the majority of these people lived in rural areas (Barbosa et al, 2004). Access to electricity in rural Amazônia is limited for several reasons, including the isolation of the communities, their distance from power generation centers, and the presence of rivers and other difficult terrain. These obstacles, and the fact that many rural consumers have lower incomes and consume less energy than urban consumers, make extending the electricity transmission grid to rural areas costly and often impractical for utilities (Zerriffi, 2008). Many rural communities without access to the grid use diesel engines to produce electricity. However, diesel fuel is expensive, produces greenhouse gas emissions that contribute to global climate change, and has other negative health effects such as causing respiratory problems and cancer due to toxic substances in the exhaust (Barbosa et al, 2004; American Lung Association).

Isolated renewable energy projects are a promising alternative to diesel power for providing electricity in rural communities not connected to the grid. However, there have been a limited number of such projects in rural Amazônia, and they often face obstacles that limit their sustainability. Evaluating the environmental, social, and economic impacts of an isolated renewable energy project will help determine the feasibility and potential for success of such a project in a rural community. Understanding the challenges and limitations that this project and others like it face can help identify solutions to these challenges and policies to ensure the success of isolated renewable energy projects.

Objectives

The specific objectives of this study are:

1. To evaluate the environmental, social and economic impact of isolated renewable energy projects through a case study of a small-scale biomass and solar energy electrification project in the community of Santo Antônio, Pará.
2. To determine whether the electrification project in Santo Antônio will be able to successfully provide energy to the community for an extended period of time.
3. To evaluate the limitations to implementing and sustaining isolated renewable energy projects and discuss policy options for increasing the number and success of isolated renewable energy projects in rural Amazônia.

Methods

Selection of the study site

The community of Santo Antônio is a riberinho community of about thirty families in the district of Breves, Pará. This community has been using energy from a biomass power plant and individual solar panels since September 2010. The electrification project was implemented jointly by Celpa, an energy utility company, and two groups from the Federal University of Pará (UFPA) – GEDAE (*Grupo de Estudos e Desenvolvimento de Alternativas Energéticas,* Group for the Study and Development of Alternative Energy) and EBMA (*Grupo de Energia, Biomassa, e Medio Ambiente,* Group of Energy, Biomass, and Environment).

Santo Antônio was chosen as the location of study for several reasons. First, since the electrification project was recently implemented, it was possible to evaluate the process of implementing the project, the current situation, and expectations for the future of the project. Also, the presence of biomass and solar energy in the same community provided the opportunity to study both mini-grid and individual isolated systems, as well as two different renewable energy sources. Finally, employees from Celpa and UFPA who were responsible for the project were traveling to the community for a meeting with community members, providing an ideal opportunity to interview both residents of the community and the professionals responsible for implementing the project.

Interviews with residents of Santo Antônio

Semi-structured interviews were conducted verbally in Portuguese with 14 residents of Santo Antônio – eleven with residents that use biomass energy, and three with residents with solar photovoltaic systems. Participation was voluntary, and interview respondents were informed that their names would not be recorded, and that they did not have to answer every question. A semi-structured interview format was used so that the same data would be collected from all interviewees while leaving room for respondents to provide insight into or clarification of their responses. All interviewees were asked the same set of fifteen questions, and follow-up questions were asked when necessary. The interview questions were designed to evaluate the electrification project on the following criteria:

- Access to electricity: for what and for how long people use electricity; whether there is always access to electricity
- Quality of life: how daily life has changed since project implementation; feelings about whether lives have improved since project implementation
- Economic impact: energy costs; changes to work as a result of electricity; whether any new economic activities started as a result of electricity
- Limitations: suggestions for improving the project; expectations for how long the project will last

Interviews with project implementers

Semi-structured interviews were conducted with Celpa's coordinator for the electrification project, two professionals from GEDAE who were responsible for the solar energy technology and the distribution of electricity through the mini-grid, and the professor from EBMA who was responsible for the biomass power plant. Three of these interviews were conducted in Portuguese and translated to English, while one was conducted in English. The interview questions varied depending on the expertise of the person interviewed, but in general these interviews were designed to evaluate the electrification project on the following criteria:

- Access to electricity: amount of electricity generated; whether there is always access to electricity; how many people the project is providing electricity for
- Environmental impact: greenhouse gas emissions; other environmental impacts
- Quality of life: changes to the community since project implementation

- Economic impact: cost of implementation; funding source; economic changes in the community
- Limitations: challenges related to the implementation of the project; expectations for how long the project will last; lessons learned from this project and past projects; challenges faced by isolated renewable energy projects in general

In addition to these formal interviews, conversations with the program implementers and personal observations provided information about and insight into the community's history and structure.

Background Information

Classifying renewable energy

Energy sources are considered renewable if the rate at which they are replenished, either naturally or artificially, is equivalent to the rate at which they are used (Barreto and Pinho, 2008). Natural renewable energy sources include solar, wind, hydro, and natural biomass. Artificial renewable energy sources include biomass that is planted or generated from industrial residues or other human-controlled activities (Barreto and Pinho, 2008). Renewable energy sources can be connected to an electricity grid and distributed by a utility or they can be used in isolated systems. Isolated systems are an example of decentralized energy, also known as distributed generation or local energy. The World Alliance for Decentralized Energy (WADE) defines decentralized energy as "electricity production at or near the point of use." While decentralized energy can be renewable or non-renewable, many of the common decentralized energy technologies, such as solar photovoltaic (PV) systems, rooftop wind turbines, small-scale hydropower plants, and biomass fired engines and turbines, are renewable energy sources (WADE, 2010).

A mini-grid is one type of an isolated renewable energy system; it provides electricity to a community by connecting a single source of energy production, such as a micro-hydro plant or a biomass power plant, to several consumers. The other type of isolated renewable energy is the individual system, or SIGFI (*Sistema Individual de Geração de Energia Elétrica com Fontes Intermitentes*, or Individual System of Electricity Generation with Intermediate Sources). Examples of SIGFIs include solar PV systems or wind turbines installed at the consumer's home. SIGFIs in Brazil are regulated by ANEEL, the national electricity regulatory agency. Consumers with SIGFIs that guarantee less than 30 kWh of electricity a month pay for the availability of this electricity, not for the amount of electricity they consume (ANEEL, 2004). There is currently no government regulation for isolated mini-grid systems (J. Pinho, personal communication, November 30, 2010).

Advantages to renewable energy projects in rural communities

There are several advantages to implementing distributed generation renewable energy projects in rural communities. First, these projects provide power at the level and times needed in rural areas, and are often more practical and cheaper than extending the grid to remote areas (Zerriffi, 2008; WADE, 2010). Access to electricity can improve quality of life by making it possible for people to use light and household appliances such as TVs and refrigerators and by creating opportunities for new economic activities such as small-scale manufacturing. Renewable energy projects can also provide an alternative fuel for cooking and transportation. Although they are often expensive to implement, renewable energy projects reduce the amount of expensive diesel fuel needed to provide electricity in communities not connected to the grid, and the projects can eventually produce savings for the community when compared with diesel power (Pinho and Araújo, 2004).

Distributed generation renewable energy projects avoid many environmental problems associated with conventional energy sources. They reduce greenhouse gas emissions at the household level and by improving efficiency through eliminating the energy lost through transport in the grid (United Kingdom, 2007). Other environmental benefits include reducing land use from transmission lines and electricity distribution infrastructure. They also lead to the reduction of resource extraction of non-renewable resources such as coal and oil and utilize materials generated in the community (e.g., animal waste or residue from a sawmill) or that are naturally abundant (e.g., wind and water) (WADE, 2010).

Limitations of renewable energy projects in rural communities

Despite these advantages, there are not many renewable energy projects in isolated communities in the Amazon. In fact, in 2006, less than 4% of Brazil's total energy generation came from renewable sources (not including large hydropower) (Volpi et al, 2006). There are several limitations to implementing renewable energy projects in small, rural communities. First, these projects are often expensive to implement. Rural communities usually do not have the capital to start such projects unless the government or an outside organization assists them (Zerriffi, 2008). Renewable energy systems also need maintenance, and often there are not people in the communities with skills to maintain the equipment or money to pay for maintenance (Barbosa et al, 2004). Electricity from isolated systems is often more expensive per kW than energy from the grid, so if the grid were to be extended, these technologies would not be economically competitive (Zerriffi, 2004). Another challenge is ensuring that there is enough electricity present to meet the demand of the community, even during peak use (Zerriffi, 2004).

There is also limited government financial support for isolated renewable energy projects. The CCC *(Conta de Consumo de Combustiveis*) is a subsidy for diesel fuel in rural communities, particularly in the Amazon, to make diesel fuel competitive with electricity from the gird (Zerriffi, 2007). This incentivizes utilities to provide electricity to rural consumers through diesel fuel, instead of developing renewable energy projects (J. Pinho, personal communication, November 20, 2010).

Renewable energy projects in rural Amazônia

The limited number of existing renewable energy projects in isolated communities in the Amazon stem from four sources: non-governmental organizations, academic research, corporate initiatives, and government programs (and often a combination of these sources). Although it is not within the scope of this paper to describe all of these projects, an overview of several types of initiatives will be presented along with examples.

Originating from the non-profit sector, projects have included individual and mini-grid isolated systems. There have been several projects to distribute solar panels to isolated communities. One NGO, IDEAAS (*Instituto para o Desenvolvimento de Energias Alternativas e da Auto Sustentabilidade)*, installed several hundred solar home systems in rural communities, and is now expanding its activities to the Amazon (Zerriffi, 2008). A mini-grid project originating from the non-profit sector was developed in 2006 in the community of Cachoeira do Aruã, Pará, by several organizations, including Winrock International Brazil, the Health and Happiness Project (Projeto de Saúde e Alegria), and a local community organization, with support from the corporate and academic actors. A mini-hydroelectric power plant of 50 kW was installed to provide electricity to 44 homes and eight other buildings in the community. The community also used the electricity to start making furniture, which they sold in the nearby city of Santarém (Oliver, 2007). This was a pilot project for the PRISMA model of electrification, which advocates using energy to mobilize local communities to develop commercial activities and lead to improvements in health, sanitation, education and economic development (Winrock, 2007). This project is still providing electricity for the community, although some of the initial partner-NGOs are no longer involved.

Renewable energy projects in rural Amazônia have also originated from academia, often with financial support from the government or private sectors. Over the past decade, GEDAE of UFPA developed and implemented several hybrid renewable energy systems in rural communities. Hybrid systems combine more than one source of energy, including at least one renewable energy source, such as wind and diesel or wind and solar power. Advantages to hybrid systems are that they are able to meet peak energy demand without interruption and respond to seasonal variability in the availability of renewable energy sources (*Sistemas Híbridos*). GEDAE developed four hybrid electricity systems in rural communities previously without electricity in Pará: two solar PV-wind-diesel systems, one solar PV-wind system, and one wind-diesel system (Barreto and Pinho, 2008). As of June 2008, none of these hybrid systems were fully functioning: one was completely deactivated due to lack of maintenance, two were running only on diesel fuel due to maintenance problems with the renewable source, and one was deactivated because the community was connected to the conventional electricity grid as part of the government's *Luz Para Todos* program (Barreto and Pinho, 2008). The maintenance problems that these hybrid systems encountered highlight the challenges faced by renewable energy projects in isolated communities.

Table 1: Description of hybrid systems developed by GEDAE in the state of Pará.

Community name	Type of energy	Year implemented	Current Situation	Reason
Joanes	Solar PV-wind	1997	Deactivated in 2005	Lack of maintenance
Praia Grande	Wind-diesel	1998	Partial operation (only diesel)	Lack of maintenance
Tamaruteua	Solar PV-wind-diesel	1999 2007 (revitalized)	Partial operation (only diesel)	Control panel broke, and funds are being raised for a new one
São Tomé	Solar PV-wind-diesel	2003	Deactivated in 2007	Extension of the conventional grid by the utility company

Source: Barreto, Eduardo Jose Fagundes, and João Tavares Pinho. *Sistemas Híbridos: Soluções Energéticas Para a Amazônia*. Brasília: Ministério De Minas E Energia, 2008. Print.

Government initiatives promoting renewable energy

In addition to non-governmental and academic initiatives, there are several government programs that promote renewable energy. A government program that targeted rural communities for electrification was PRODEEM (*Programa de Desenvolvimento Energético de Estados e Municipios*). Established in 1994, PRODEEM provided solar photovoltaic systems to electrify community buildings such as schools and clinics in rural areas (Zerriffi, 2008). Although 8,700 units were installed under the program, the solar systems faced problems with maintenance of the equipment, and many of the systems are no longer functioning (Zerriffi, 2008).

PROINFA (*Programa de Incentivo às Fontes Alternativas de Energia Elétrica)* is a program that began in 2002 to increase energy generation by wind, biomass, and small-scale hydropower. Its goal is to have alternative renewable energy sources (renewable energy not including large hydropower) provide 10% of the total electricity supply in Brazil by 2022 (Geller et al, 2004). Although this program has led to an increase in renewable energy, especially wind power, its focus is on grid-connected systems, not on rural communities.

Finally, the *Luz Para Todos* program is a federal initiative to provide electricity to those in rural areas without access to it. Under this program, utilities have a deadline of 2015 to provide electricity for all of the consumers in their area of service, with financial incentives to meet this deadline by 2008 (Zerriffi, 2008). Although *Luz Para Todos* does not focus specifically on renewable energy, the financial resources and requirements it provides may incentivize utilities to develop renewable energy projects in areas where grid extension is costly and impractical.

Table 2: Description of the major government programs relating to isolated renewable energy systems.

Program name	Year implemented	Description	Relationship to isolated renewable energy systems
PRODEEM	1994	Provide solar PV systems to community structures in rural communities.	Promotes isolated renewable energy systems, but not focused on households.
PROINFA	2002	Increase electricity generation from alternative renewable sources.	Promotes grid connected renewable energy, not isolated systems.
Luz Para Todos	2003	Goal of universal electricity access.	Provides incentives for utilities to electrify rural communities, not necessarily with renewable energy.

Results

Characteristics of the study site

Santo Antônio is a riverside community of about thirty families. The community is only accessible by boat, and it is a three hour motorboat or eight hour passenger boat ride away from Breves, the closest city. Out of the families interviewed, an average of 6.2 people live in each household. The majority of families live on one side of the river, but there are four isolated houses on the other side of the river, 300 meters away. The majority of people in the village work at a sawmill owned by Nene, the unofficial community leader. Seven of the eight males interviewed work at the sawmill or the adjacent power plant. Four out of the six women interviewed work at home. Several years ago, activity at the sawmill started to slow down because new regulations from IBAMA restricted the wood from the area that could be used. The sawmill is no longer operating at full capacity, and the majority of the manufacturing that takes place there is making broom handles, which are sold to nearby cities. The sawmill also processes wood that is collected by people in other communities.

Nene used to use a diesel motor to power the sawmill during the day and to provide electricity to people's homes at night. He would pay R$480 a month for electricity from the diesel motor. When the environmental regulations limited the activity at the sawmill two years ago, the diesel electricity was stopped. The homes in this community had been without electricity for two years before the implementation of the biomass power plant in September of this year.

Table 3: Interview respondents by gender and profession.

Job	Male	Female
Work at sawmill/power plant	7	0
Domestic work	0	4
Teacher	0	2
Foreman	1	0
Total	**8**	**6**

Table 4: Number of households and number of interview respondents by type of energy.

Electricity source	Number of households	Number of people interviewed
Biomass	25	11
Solar	4	3

Description of the electrification project

Celpa and UFPA chose the community of Santo Antônio for this electrification project for several reasons. Due to the federal government's *Luz Para Todos* program, utilities will be responsible for providing electricity to all people living in the area they serve, even remote communities. Celpa is anticipating this need to provide electricity to isolated areas, and is researching how to effectively do this through alternatives to grid extension; Santo Antônio is a pilot project for them. This community was chosen for the project because it was possible to install both a mini-grid and individual systems in the same community. The dispersed houses on one side of the river were ideal for individual solar systems, while the majority of the community on the other side of the river was better for a mini-grid because the homes are clustered in one area. Santo Antônio was already producing residue from the sawmill, making it a good place for biomass energy. Also, this community was well organized and had a leader who was passionate about the project, making it likely that the project would be able to be operated and maintained through a cooperative. Celpa's department of research and development paid for this project, which cost a total of R$1,200,000 to implement. The researchers from UFPA provided the technical support for the project.

Table 5: Overview of the groups involved in the Santo Antônio electrification project and their roles in the project.

Actor	Sector	Role in Project
Celpa	Private (energy utility, subsidiary of Rede Energia)	Funding, community relations
GEDAE (Group for the Study and Development of Alternative Energy)	Academic (UFPA)	Install the solar panels and the mini-grid
EBMA (Group of Energy, Biomass, and Environment)	Academic (UFPA)	Construct the biomass power plant

Description of the biomass power plant

The activity at the sawmill creates a lot of residue, extra pieces of wood that can't be used for manufacturing, which makes it an ideal place to utilize energy from biomass. Before the implementation of the biomass power plant, the residual wood would be left to decompose or be burned, and now it is used to generate electricity. The 15 kW mini power plant burns the wood residues, and the heat from this process is transferred to a steam boiler. The steam is used to spin a turbine, which generates electricity. The steam is cooled and condenses back into water, which is reused. The professor from EBMA responsible for the biomass technology reported that this power plant has a net zero carbon footprint, but two other people working on the project disputed this claim, maintaining that the amount of the emissions was small but existent. Emissions from burning biomass are much lower than those from diesel fuel, especially when considering the fact that the wood burned to generate electricity would have decomposed or been burned regardless of whether any electricity was generated from it. Also, this power plant uses filters to reduce the pollution from burning the wood.

In Santo Antônio, the power plant provides energy to the community through a mini-grid from 7am to 11pm each day. It has the potential to power the community for 24 hours a day, but the community decided that they didn't want electricity at night. Two people work at the plant in 8-hour shifts. Beginning on the day that the interviews were conducted, the power plant will be operated by a cooperative of the people in Santo Antônio. The consumers will pay based on how much electricity they use, calculated from monthly readings of meters on each home. In addition to all of the homes on this side of the river, the power plant is providing electricity for two churches, a school, the broom factory and sawmill, a snack shop and a club.

Figure 1: Wood being added to the boiler in the biomass power plant.

Figure 2: Meters on each home show the monthly electricity consumption.

Description of the solar panels

On the other side of the river, the four dispersed houses cannot be connected to the mini-grid because it is difficult and costly to install power lines across a river. These homes did not have electricity before this year because they were not provided with electricity from the diesel motor when it was operating. As part of the electrification project, solar photovoltaic systems were installed at the four isolated houses. Each solar PV system has 170 Watts-peak (Wp) of power, consisting of two PV modules of 85 Wp each. The minimum energy availability per month, based on the month with the least solar radiation in this location, is 13 kWh. The houses with solar energy are not part of the cooperative, and Celpa will maintain the solar PV systems, which are classified as SIGFIs and regulated by ANEEL. Since these solar photovoltaic systems have 13 kWh of electricity guaranteed to the consumer, the consumers will pay Celpa a fixed rate for the availability of electricity.

Solar PV systems convert sunlight directly into electricity. When the semi-conductor materials of the photovoltaic cells absorb sunlight, the solar energy knocks electrons loose. These electrons then move to a circuit in the photovoltaic cell, creating an electrical current ("Energy Savers", 2010). The major environmental impacts associated with solar energy occur in the manufacturing and transport of the photovoltaic systems. Some of the materials in the photovoltaic systems, such as silicon, cause a lot of pollution and carbon emissions to produce. There are also carbon emissions associated with transporting the systems from where they are manufactured to where they are used. However, solar photovoltaic systems do not require much land or deforestation, and once they are installed, they do not produce any carbon emissions.

Figure 3: A solar photovoltaic system being repaired in front of a home in Santo Antônio.

Perspectives of the residents of Santo Antônio

Past situation

When diesel fuel powered the community, the people with electricity reported that it was available for an average of 3.7 hours a day. All of the homes in the community were without electricity for two years before the implementation of the biomass power plant, and the isolated homes that received solar panels never had electricity. The people with biomass energy have had their appliances for many years (they bought them an average of 4.3 years ago). The people with solar panels got their appliances when the electricity was installed two months ago. They were given lights by Celpa, and bought any other appliances on their own.

Current situation

The interviewees use electricity for an average of 9.0 hours per day. The interviewees using biomass energy use electricity for slightly more time each day than those with solar energy. The interviewees with biomass energy spend an average of 4.2 hours a day watching TV, while none of the people with solar power interviewed had a TV in their home.

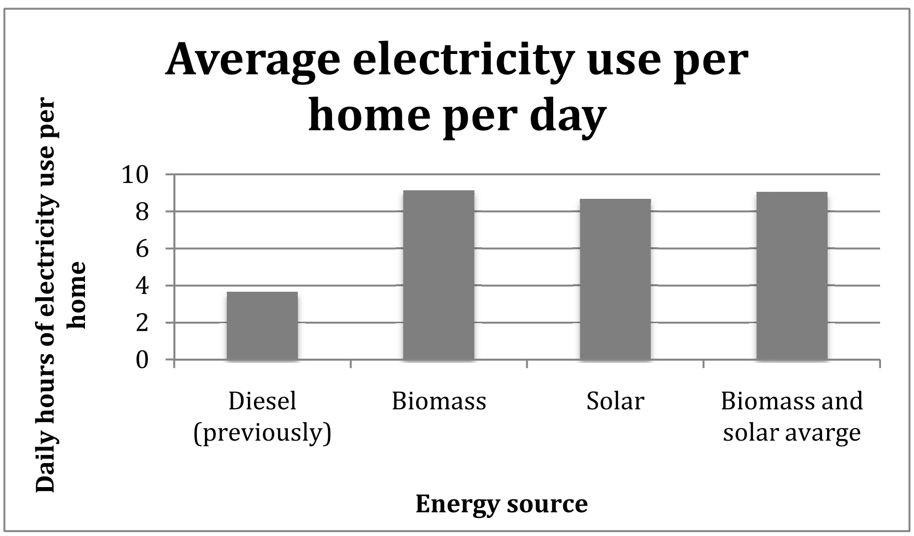

Figure 4: When Santo Antônio had electricity from a diesel motor, electricity was only available for 3.7 hours a day. Now, electricity is available for 16 hours a day, and residents use electricity for an average of 9.0 hours a day. Residents with biomass energy use electricity slightly more each day than those with solar energy.

Everyone interviewed uses electricity for lighting in his or her home. Out of the eleven respondents with biomass energy, eight have a television in their home, four have a refrigerator, three have another type of entertainment equipment, three have a washing machine, two have a freezer, two have a cooling device (fan or AC), and one has a machine for making açai pulp. Of the three people with solar energy interviewed, the only appliance in addition to lighting was a radio in one of the homes.

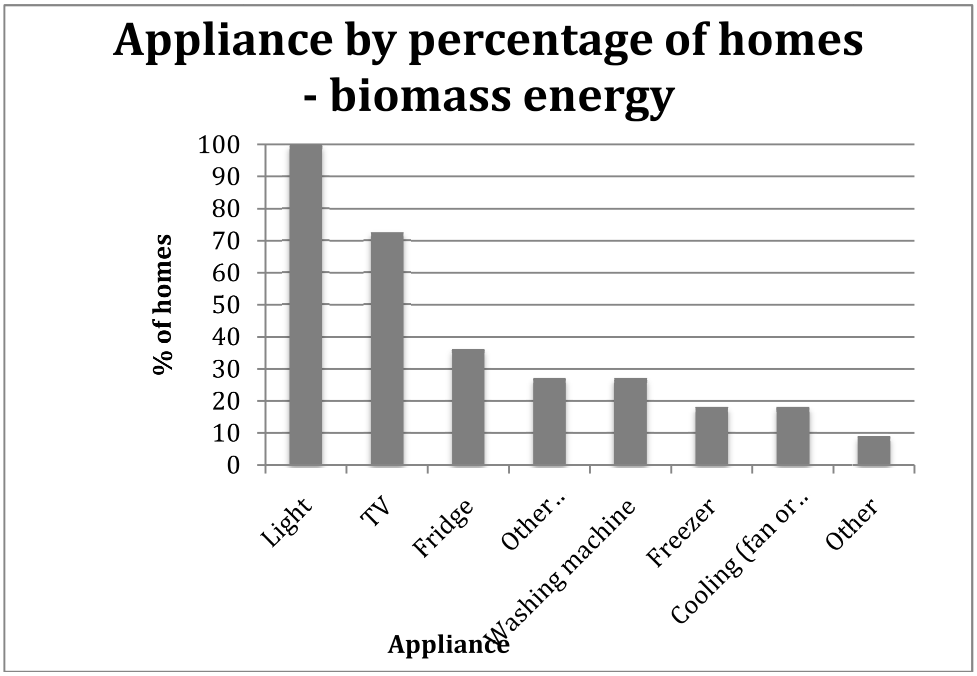

Figure 5: All of the interviewees with biomass energy have light in their homes, over 70% have televisions, and over 30% have refrigerators.

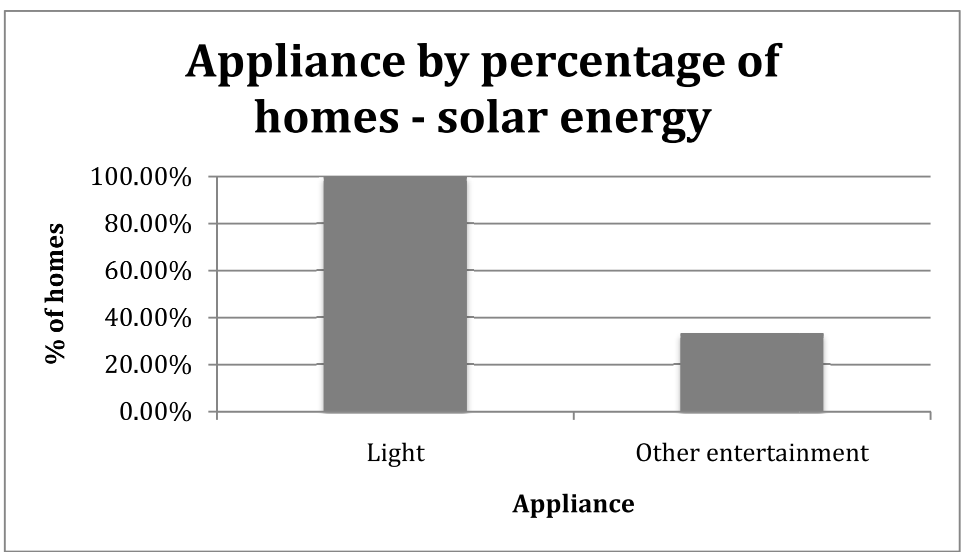

Figure 6: Aside from lighting, the only appliance present in the homes of people interviewed with solar energy is a radio in one of the homes.

Half of the people interviewed said that their work had changed as a result of the project. Two of these people work in the school and said that the school never lacks electricity now, two work at home and use the electricity to operate a washing machine, and three work at the sawmill or power plant. Only two people said that they make more money as a result of this project – the sawmill owner who no longer has to pay for diesel fuel, and the power plant operator whose salary is higher than it was at his previous job at the sawmill.

Since this project was implemented so recently, the monthly cost to each consumer is not yet known. For the biomass energy, the consumers will pay R$0.25 per kW hour of electricity, and are estimated to have monthly costs of R$10-30 a month. For the solar PV systems, the expected cost to the consumers is R$10-15 a month, but since this amount is so small, Celpa might not charge them anything.

For the biomass energy, there have not yet been any instances when the electricity did not work when it was supposed to. Two out of the four solar panels were not working for a period of ten days due to a problem with their batteries. The technicians from GEDAE were able to repair these panels when they visited the community.

Feelings about the electrification project

Every interviewee responded that their life is better now than it was before they got electricity. When asked how their lives had changed as a result of getting electricity, out of twelve respondents, with more than one response per person possible, five people responded that they now have light or energy at night, five people mentioned the ability to watch TV, two people discussed the certainty of having electricity, two people discussed having access to cold water, one person said that the electricity helped business, and one person said that it gave them the ability to wash clothes in a machine.

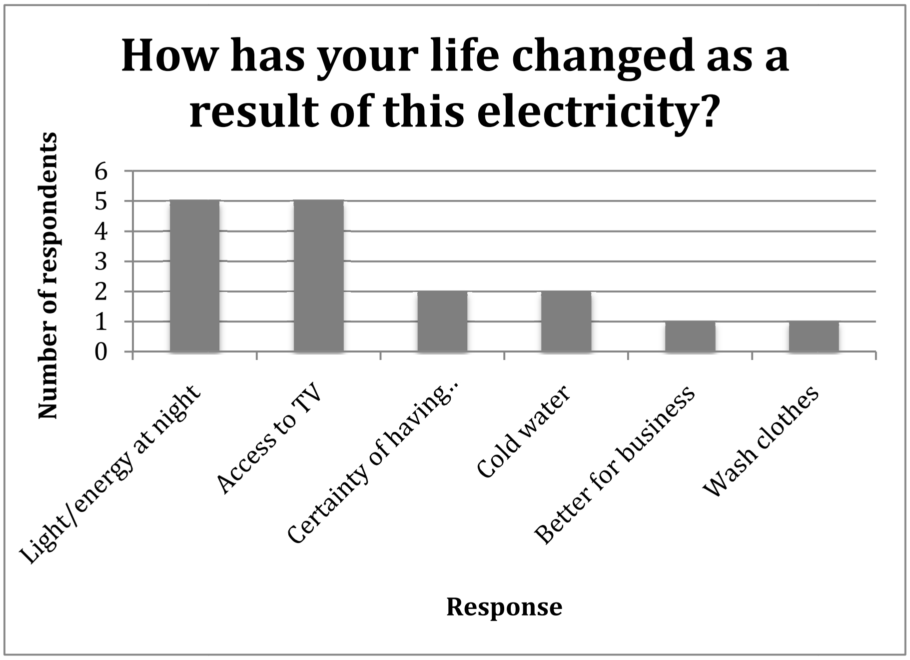

Figure 7: When asked how their lives had changed as a result of the electrification project, the most common responses were having access to light and energy at night, and having access to television.

When asked how this project could be improved, out of fourteen respondents, four people replied that the electricity should be used for another productive activity, in addition to the sawmill, that could provide jobs for people. Suggestions for this activity included an ice factory and açai production. Two people responded that they would have liked help buying appliances to use the electricity for (both of these people had solar panels, so did not have electricity in their homes and a reason to buy appliances before this year). One person responded that community members shouldn't have to pay for their electricity, one person responded that electricity should be available 24 hours a day, and one person said that the solar panels would work better with more sun. Five people responded that there was no problem with the project, or they did not know how it could have been improved.

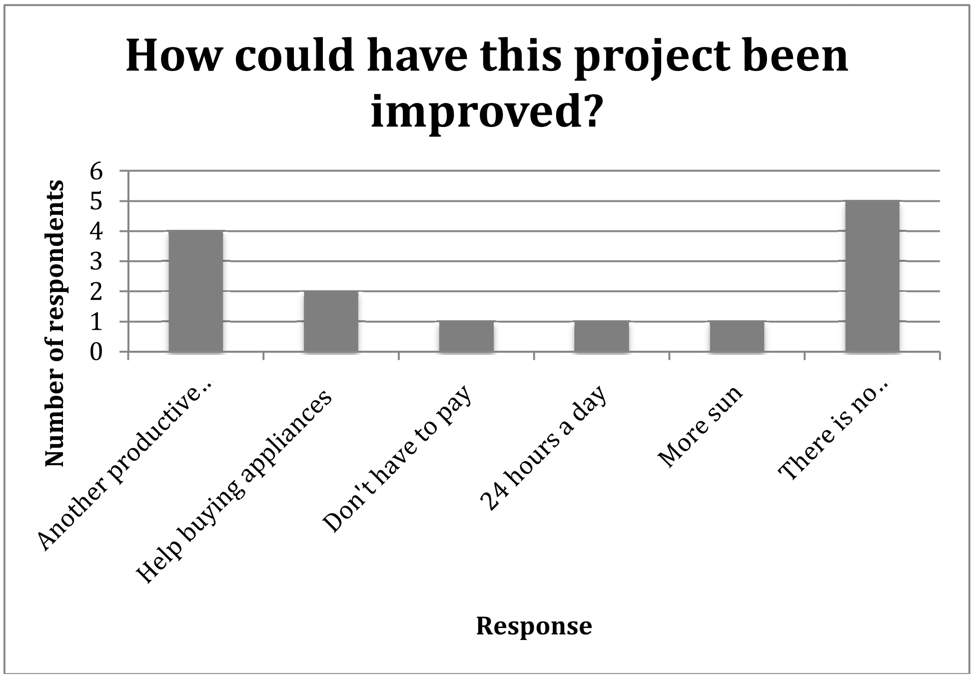

Figure 8: When asked how the electrification project could be improved, the most common suggestion was the development of a productive activity to use electricity for.

Expectations for the future

When asked how long they expected to receive energy from this project for, people with biomass energy were considerably more optimistic than those with solar panels. Out of 11 respondents with biomass energy, four people responded that the electricity would last for the rest of their lives, three said it would last "a long time" or "many years", one person said it would last for 25-30 years, and one person responded that it would last for 5 years. Two people responded that they didn't know. Out of the three interviewees with solar panels, on the other hand, one person said that electricity from the solar panels would last 3-4 months, one person said that it would last one month, and the third responded that he was unsure how long it would last, but "maybe for a month or a year".

Perspectives of the project implementers

Impact on the community

Since Santo Antônio received energy very recently, the interviewees from UFPA and Celpa thought that it was hard to evaluate the impact of the project on the community. They said that the people in the community were happy about the project and now have more access to information, and that they are looking for another productive activity to use the electricity for, such as ice making or açai production, that could increase income in the community.

Room for improvement

The people interviewed mentioned several problems with the project or ways in which it could have been improved, largely relating to the equipment used. One problem was that commercial technology doesn't exist for many of the materials that were needed. For example, the turbine used in the biomass power plant was not manufactured in Brazil, and took nearly a year to be produced and shipped, slowing down the implementation of the project. In terms of the photovoltaic systems, the battery bank could have had a higher capacity so that each charge would last longer. Both interviewees from GEDAE had wanted to use a pre-pay payment system for the mini-gird, and mentioned advantages to this method of payment relating to the sustainability of isolated systems and the conservation of electricity. However, pre-pay meters are four to five times more expensive than conventional meters, so a decision was made not to use them.

Perspectives for the future

A cooperative of community members is responsible for the operation and maintenance of the biomass power plant, which is expected to cost R$11,500 a year, plus the salary of the operators (R$45,000). The maintenance activities that the community will be responsible for are: an annual hydrostatic test carried out by a team of technicians (R$1,000); an annual analysis of gas and particulate matter, carried out by a team of technicians (R$5,000); weekly cleaning of the boiler by the power plant operator; and an annual oil change for the turbine (R$2,500). They will also pay about R$300 a year for the cost of materials consumed (Celpa, 2010). The people who work at the power plant are trained in basic maintenance activities, and the person responsible for the project for Celpa did not think that the community would face any problems with maintenance, because the power plant does not require much maintenance, and Celpa is responsible for the maintenance of the solar panels.

Table 6: Description of maintenance activities for the biomass power plant

Activity	Frequency	Cost (R$)
Hydrostatic test	Yearly	1,000
Analysis of gas and particulate matter	Yearly	5,000
Oil change for the turbine	Yearly	2,500
Cleaning of the boiler	Weekly	N/A

Source: Celpa: Rede Energia. *P&D Comunidades Isoladas: Comunidade Santo Antônio*. Nov. 2010. PPT.

The interviewees from GEDAE thought that the project would be successful because the community has a strong leader, the owner of the sawmill, who has an interest in keeping the power plant running. Also, they mentioned that the community has been trained in the maintenance of the power plant and shown how to raise enough money from the consumption of electricity to pay for the operation and maintenance of the system. Some of this training occurred in a meeting on the day that the interviews were conducted, in which control of the biomass power plant was officially given to the cooperative. One potential problem mentioned regarding the sustainability of this project was the fact that the sawmill is not running at full potential due to the restrictions from IBAMA, so people need to look for new sources of income and other productive activities to use the electricity for.

Discussion

Socio-economic impacts

People in Santo Antônio have positive feelings about the electrification project. Electrification improved the quality of life in the community by allowing people to have light and use energy at night, watch TV and become more informed about the world, and use energy to make some household tasks easier. Residents did not buy many additional appliances as a result of this project, probably because the people with biomass energy already owned many appliances from when there was diesel energy, and the people with solar energy have not had electricity for enough time to save to buy new appliances. People now spend more time using electricity and watching TV than they did before the electrification project, and they view this as a positive development.

In terms of economic impact, few people make more money as a direct result of this project. However, the cost of energy is lower than it would be to produce an equivalent amount of energy with diesel fuel (R$11,500 a year for biomass energy versus over R$200,000 a year for diesel fuel). Also, the community is very interested in using the electricity for a productive activity, such as an ice factory, açai production, or clothing production. These types of activities would supplement the incomes of community members.

Environmental impacts

Compared to diesel fuel, the environmental impacts of both solar and biomass energy are considerably lower. For solar energy, most of the environmental impacts come from the production and transport of the photovoltaic units – there is virtually no environmental impact once the solar panels are installed. Generating electricity from biomass produces some carbon emissions. However, the wood residues are already present in Santo Antônio, and would either be burned or decompose if not used to generate electricity; the majority of the carbon emissions from biomass energy would be produced anyway. "All energy generation has some kind of impact," said an interviewee from GEDAE. Although they are not without impact, both solar and biomass energy have much lower carbon emissions, pollution, and negative health effects than diesel power, the most common electricity source in isolated communities.

Outlook for the future

Limitations

A possible problem with the biomass power plant is the fact that the sawmill is not running at full potential, so the cooperative could eventually run out of residues to burn. Also, although the cost of electricity is supposed to cover the operation and maintenance of the system, this depends on the level of electricity consumption, and it is possible that when parts need to be replaced, there will not be enough funds to cover this. In terms of the solar PV systems, Celpa will be responsible for maintenance, but when there are problems the consumers will have to contact workers from the utility and have them come repair the system, which might prove to be a problem due to the isolation of the community.

Lessons from the failure of previous isolated renewable energy systems informed the way in which this project was implemented. For example, several of the hybrid system projects that GEDAE worked on in the past failed because when there were maintenance problems, the community could not organize to raise money to repair the systems. Santo Antônio was chosen for the project largely because it has a strong community organization and a leader who would take responsibility for the project, making it less likely that it would run into similar problems. In addition to these lessons about the necessary social structure of the community, improvements have been made to the technology of the solar PV systems to make maintenance easier.

Prospects for success

Overall, both members of the community and the professionals responsible for the electrification project were optimistic that the project would be successful and last a long time. Due to the leadership structure in the community, the fact that community members are trained in the maintenance of the biomass power plant and Celpa will provide maintenance of the solar panels, and the fact that electricity can help this community economically and socially, it seems likely that Santo Antônio will receive electricity from biomass and solar energy for many years.

This project will be even more successful if the community is able to use electricity for a productive activity. The coordinator for the project for GEDAE explained that since the sawmill is no longer running at full potential, there is a great need for the community to develop another economic activity, and they will be able to use electricity for such an activity. In order for this to happen, he said, "they will need someone who will instruct them, who will lead the people in this way of searching for the things and making this small production really good… I think they will have help from the outside". One possibility is that they will receive assistance from SEBRAE (O Serviço Brasileiro de Apoio às Micro e Pequenas Empresas), a non-profit organization that "promotes the competitiveness and sustainable development of micro and small businesses" (SEBRAE, 2010).

Renewable energy in rural Amazônia

Community characteristics

From a technological standpoint, renewable energy projects can easily be implemented in rural communities. However, for such projects to be successful, the community should be well-organized, whether it has one clear leader like Santo Antônio or a strong cooperative or community organization already in existence. In addition, the community should have some resource that can be utilized for energy, whether it is residues for biomass energy or a sufficient amount of wind and sun for a hybrid system. Also, in order for the community to benefit economically from the electricity, they should be able to develop a productive activity, such as a small manufacturing project, that can supplement the incomes of the people in the community.

Planned projects

There are several projects similar to the electrification project in Santo Antônio planned for other rural Amazonian communities. GEDAE and EBMA are in the process of constructing three floating hybrid systems that will be brought to riberinho communities. One of these systems runs on photovoltaic, hydrokinetic, and biodiesel power, and the other two run on hydrokinetic and biomass energy. All of the systems have ice production and oil production units on the floating barges. Once these barges are towed to communities, they will provide electricity for the communities through a micro-grid and the residents will be able to use the barges to produce vegetable oil for energy and to sell and ice to preserve the fish they catch (GEDAE, 2010). There are several advantages to the floating hybrid system projects, including that they utilize resources available in the community, use a hybrid of sources to ensure constant availability of electricity, and can be moved to another location if the community is ever connected to the conventional electricity grid.

In terms of corporate initiatives, Celpa, along with Eletrobras, is developing another pilot project in Araras, Pará, which consists of a hybrid system and three solar photovoltaic systems that will generate 10 kW of electricity for the community (Canal Energia, 2010). Eletrobras, with government support, is also investing in projects in isolated communities under its "Special Projects" program.

Government policies to promote renewable energy

Although the technology exists for renewable energy projects in isolated communities, the political will, and therefore the financial resources, for such projects is lacking. One problem is that there is no regulation in place for mini-grid isolated systems, so utilities are hesitant to implement them, fearing that they will lose money. If there existed the same kind of regulation for mini-grids as there are for SIGFIs, renewable energy projects connected to mini-grids like the biomass power plant in Santo Antônio would likely be developed by utilities and used in more isolated communities. Another government policy limiting the spread of renewable energy in isolated communities is the CCC diesel subsidy. If this subsidy were extended to include renewable energy, it would become much more cost effective for utilities to provide electricity through renewable sources.

In order to make renewable energy economically competitive with other energy sources, it should be deployed on a larger scale in order to spur technological innovation. A GEDAE professor explained that if grid-connected systems used more renewable energy sources, there would be technological improvement. “When the technology improves, the prices go down for the grid connected systems, and that’s good for the isolated systems because you get easier access to the technology at a cheaper price.” Although Brazil’s use of renewable energy such as wind and solar power is growing, it is still small compared to the amount of energy it gets from other sources, such as large hydroelectric power plants. In addition, despite the fact that the majority of renewable energy projects in isolated communities in the Amazon have originated from the private, non-profit, and academic sectors, the government’s role in such projects seems to be expanding, as evidenced by programs such as PROINFA and *Luz Para Todos*. Government programs such as PRODEEM and PROINFA have promoted renewable energy, and similar programs could be developed to provide renewable energy to rural consumers at the household level in addition to through grid-connected systems or individual community structures.

Conclusion

The electrification project in Santo Antônio will likely provide energy to the community for many years to come, due to the community’s strong organization and leadership and plan for maintaining the equipment. The electricity provided by this project helped the community socially by providing more connection to the outside world through increasing television access, and by making household tasks easier. It also helped the community economically by eliminating the need to pay for expensive diesel fuel and by providing the opportunity to use electricity for a productive economic activity. In addition to these socio-economic benefits, there are environmental benefits to the project, including low carbon emissions, little land required, and productively using residues from the sawmill. Although one would expect other isolated renewable energy projects in rural communities to have similar socio-economic and environmental impacts, further research is needed to evaluate this.

Isolated renewable energy projects in the Amazon face many challenges, including obtaining funding for the projects, maintaining the systems, and developing productive uses for electricity. As more and more such projects are developed and implemented, lessons and best practices will be learned from previous projects, and some of these limitations will be overcome. In addition, government policies and programs that provide funding and regulation could help to expand the number of renewable energy projects in rural communities. Given the socio-economic and environmental benefits to isolated renewable energy projects, the government should increase its support for such projects in its efforts to provide universal electricity access.

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Appendix

Interview #: M/F: Location: Electricity Type:

Perguntas para os moradores de Santo Antônio (*Questions for the Residents of Santo Antônio)*:

1. Quantas pessoas moram em sua casa?
   How many people live in your house?

   a. Quem são as pessoas?
      Who are the people?

2. Você tinha eletricidade em casa antes da chegada da energia biomassa/solar?
Did you have electricity at home before the arrival of biomass/solar energy?

   a. Por quantos horas do dia?
   For how many hours a day?

3. Para que você usa a eletricidade?
   Lâmpadas: Televisão: Rádio: Geladeira:
   Outros aparelhos elétricos:
   What do you use electricity for? (lights, television, radio, refrigerator, other appliances).

4. Quando você comprou...?
   Lâmpadas: Televisão: Rádio: Geladeira:
   Outros aparelhos elétricos:
   When did you buy....(lights, television, radio, refrigerator, other appliances)?

5. Quantas horas por dia você usa a eletricidade?
   How many hours a day do you use electricity for?

6. Quantas horas por dia você assiste à televisão?
   How many hours a day do you watch television?

7. Qual é o seu trabalho?
   What is your job?

8. Usa a eletricidade para seu trabalho? Para que?
   Do you use electricity for your job? What for?

9. Seu trabalho mudou por causa da eletricidade? Como?
   Has your job changed as a result of the electricity? How?

   a. Você ganha mais dinheiro agora? Quanto mais?
      Do you make more money now? How much more?

10. Quanto você paga em média pela eletricidade a cada mês?

How much do you pay on average for electricity each month?

11. Como a sua vida mudou após a eletricidade?
    How has your life changed as a result of the electricity?

12. Você acha que sua vida é melhor agora, ou foi melhor antes da chegada da eletricidade? Por quê?
    Do you think your life is better now, or was it better before the arrival of electricity? Why?

13. Como você acha que este projeto poderia ser melhorado?
    How do you think this project could have been improved?

14. Há momentos em que a eletricidade não funciona?
    Are there times when the electricity doesn't work?

    a. Quantas vezes?
       How many times?

    b. Por quanto tempo?
       For how long?

15. Por quanto tempo você espera receber eletricidade com este projeto?
    For how much time do you expect to receive electricity from this project?

Outras observações:
Other observations:

Acronyms and abbreviations referenced

ANEEL – Agência Nacional de Energia Elétrica (National Electricity Regulatory Agency)

CCC - Conta de Consumo de Combustiveis (Account of Fuel Consumption)

EBMA - Grupo de Energia, Biomassa, e Medio Ambiente (Group of Energy, Biomass, and Environment)

GEDAE - Grupo de Estudos e Desenvolvimento de Alternativas Energéticas (Group for the Study and Development of Alternative Energy)

IBAMA – Instituto Brasileiro de Meio Ambiente e Recursos Naturais (Brazilian Institute for the Environment and Natural Resources)

kW – kilowatt

kWh – kilowatt-hour

PRODEEM - Programa de Desenvolvimento Energético de Estados e Municipios (Program of Energy Development for States and Cities)

PROINFA - Programa de Incentivo às Fontes Alternativas de Energia Elétrica (Program of Incentives for Alternative Sources of Electricity)

PV - photovoltaic

SEBRAE - O Serviço Brasileiro de Apoio às Micro e Pequenas Empresas (The Brazilian Service of Support for Micro and Small Businesses).

SIGFI - Sistema Individual de Geração de Energia Elétrica com Fontes Intermitentes (Individual System of Electricity Generation with Intermediate Sources)

UFPA – Universidade Federal do Pará (Federal University of Pará)

Wp – Watt-peak