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SUSTAINABLE DEVELOPMENT WITH MICRO HYDRO SCHEMES IN REMOTE AREAS IN THE AMAZON REGION

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The study identified the advantages of installing micro hydro power units in remote areas in Brazil when compared to other renewable sources and to diesel generators. The run-of-the river scheme was acknowledged as the most suitable technology to be implemented in the Amazon region because of its low impact over the environment. The potential locations that could benefit from this scheme were identified and the communities' social, cultural, technological, economical, political and demographic aspects were outlined.

The project used data from previous reports to simulate the energetic demand of a standard community from the region and create a project that could be eligible to apply for carbon credits in the CDM scheme. It was calculated the amount of CO2 saved with the substitution of diesel generators for micro hydro schemes using the designated approved baseline. An economic analysis was made to justify that the CDM scheme can be used to fund partially the installation of micro hydro schemes in remote areas in Amazon.

Palavras-chaves: sustainable development, micro-hydro, electrification, Amazon

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Abstract

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Keywords: micro-hydro, renewable energy, remote areas, electrification

1. Introduction

1.1. Aims of the study

The main objective of this study is to demonstrate how micro-hydro schemes can be successfully installed in unelectrified remote areas in Brazil, providing electricity for isolated communities or substituting diesel generators that are not cost-effective and emit carbon dioxides. It also aims to show that these schemes can be funded by carbon markets, especially the Clean Development Mechanism from Kyoto Protocol, transforming it into a viable solution in the financial aspect.

1.2. Methodology

The main problem that this study addresses to is how to supply electricity to isolated communities in Brazil in a clean and sustainable way. These sites are usually far away from the grid and their inhabitants are deprived from basic infra-structure. In the case of Brazil, the villages are most of the times inside the Amazon forest, which brings even more challenging obstacles, such as environmental impacts that the electrification program might cause and economical viability that can be compromised by long distances and logistic problems. The main hypothesis formulated is “It is possible to supply electricity in remote areas in Brazil with micro-hydro schemes, stimulating renewable sources, promoting a sustainable way of life for the inhabitants and getting funds through the CDM scheme.”
To achieve the desired results, the following methodological procedures were used:

- Research - bibliographic review, including journals, books, technical reports, norms, regulations and an interview with Professor Geraldo Lucio Tiago Filho, director of National Reference Centre for Small Scale Hydropower Units (CERPCH) in Brazil.
- An analysis of existing electrification projects in remote areas was carried out to derive variables for the development of the project in this study.
- Technology analysis – Analysis of the types of technology used in micro hydro units and comparison with other renewable sources to outline their potential use in our case study.
- Geographical delimitation – definition of the sites were the case study could be applied successfully according to literature review and existing cases.
- Use of gathered data to calculate the amount of CO_2 that would be saved using the micro hydro technology with the CDM approved baseline that suited the project; estimate of the funds that would be available through this scheme.

1.3. Micro-hydro schemes

There is some concern about the environmental impact that the hydro power installations can create with the dams[1], but in the case of small hydro schemes, the units are in most cases 'run-of-river'; in other words, any dam or barrage is quite small, usually just a weir, and little or no

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[1] A barrier constructed across a waterway to control the flow or raise the level of water, creating a reservoir.

water is stored. Therefore run-of-river installations do not have the same kinds of adverse effect on the local environment as large-scale hydro (British Hydropower Association).

The most common adverse impacts found in a hydro power installation are:

- Vegetation removal in the area of installation, which can be compensated with the reforestation in another area. Also, if the unit is small, the vegetation loss will be unimportant;
- If there is a dam, its filling impacts directly on the natural landscape and ecological characteristics of the site, causing a serious break on its fauna and flora;
- Erosion in the areas where there vegetation was removed, that can consequently cause river sedimentation. This is a very serious impact that needs to be mitigated and controlled during the whole installation and operation of the hydropower unit;
- Water quality alteration with the increase of sediments in the river or with the change of oxygen percentage in the water. This could interfere in the aquatic ecosystems and needs to be monitored.
- Interference in the fish population, especially in the brands that migrate, because the hydropower unit creates an obstacle in the river that they need to overcome. Also, the river flow is diminished by the weir and intake installation, impacting on the paths the fish need to make on its lifecycle.

This study mainly addresses to micro-hydro with “run of the river” technology, meaning that the installation does not have a dam, but simply pipe water from an intake in the stream down to the generator house. These installations are designed to attend a small community, typically the occupancy pattern found in the Amazon forest in Brazil. This choice was made because of a number of reasons:

- All the turbines will be running without a dam. This means no area will be flooded and the vegetation in the surrounding area will be preserved, minimizing drastically the environmental impacts over the Amazonian biome.
- Although the dry season (that occurs between the months of June and September) might interfere in the turbines efficiency and consequently the power output, most of the rivers will still have a reasonable amount of water. The minimum flow can be used as the parameter to calculate the turbine’s power output.
- The only civil work needed is the construction of a weir and an intake to divert some of the flow from the river. The weir comes with a grid that prevents fish and sediments to get inside the turbine, minimizing the impact on aquatic life.

Another technology available that doesn’t use dams is the hydrokinetic turbines. Unfortunately, their use in this scheme would interfere in the river navigation (since they are installed in the middle and in the deepest part of the river) and the rivers in Amazon usually have a slow flow and are widely used for navigation. The scenario would limit the amount of power produced by this installation and make some communities access even more difficult.

Clearly, micro-hydro schemes cannot be used in every situation, because hydropower is site-specific, every scheme is entirely dependent on the site characteristics.

1.4. Advantages and disadvantages of micro-hydro when compared to other renewable energies

Advantages (Langley, et al., 2004)

It has a high efficiency (between 50 to 80%) compared with other renewable energy sources. Solar power (PV) has around 12-18% efficiency factor and wind power around 30-35%.

Power is produced at a fairly constant rate, and is available at any time, so there is no need to have batteries to store it, like solar power or wind power.

The technology is very adaptable, simple and easy to manufacture and use in remote areas. It is also very common in Brazil, making it easy to find equipment and experienced people to work with it.

No primary fuels are required and the maintenance costs are low.

The lifespan can be over 20 years without requiring significant further investments.

Disadvantages (Langley, et al., 2004)

It is a site-specific technology. It is required to be close to a water source to make the installation and energy transmission viable.

Each stream has an amount of embodied energy that can be converted into electricity and it can't be expanded beyond that limit if the load increases.

Civil works are needed for the hydropower installation, in particular for the construction of the penstock, the intake and the Power House.

The output can be dependent on the weather in "run-of-river" schemes, since the flow will be varying with the rainfall patterns.

There is a low-level environmental impact on the water course. The following features will be affected: amount of water in the section of the river where the water is diverted; oxygenation levels, with potential interference in the aquatic life.

1.5. Electricity for isolated communities

According to MME, in 2004 Brazil had about 2 million rural houses without mains electricity supply, most of them (80%) in the North and Northeast regions, including the Amazon forest. That corresponds to approximately 10 million people without access to electricity. Most of these communities are located in isolated areas in the North of the country with difficult access, making the grid extension unviable because of the long distances, high cost per attended unit or environmental impact that this action might cause. The most affected states are located in the Amazon forest.

The use of diesel generators to produce energy is commonly applied in the isolates regions is Amazon, because it is the easiest way of generating energy in these areas and sometimes it is interesting for the councils to have fuel coming to its site, since it generates tax incomes.

This fuel-based generation emits a lot of carbon dioxides in its life cycle – first from the extraction and refinery process; then from burning the diesel in the generator; lastly, with the fuel´s transport, that usually happens in trucks or boats that are also burning fuel to get to their destination.

The difficulties that were detected with the use of diesel generators are:

- Can create corrupt schemes of fuel deviation;
- Is not reliable, because of the fast equipment deterioration in the Amazon environment and poor maintenance with logistic difficulties;
- Submits the population to constant failure in the electricity supply;
- Requires the CCC subside, divided by all the consumers in the country in the order of billions of reais per year (ANEEL, 2009).

To minimize this situation, in 2003, the government launched a project called "Luz para Todos" (Light for All), that intends to supply electricity for everyone that doesn´t have access to it – the aim is universal access. When the grid extension is not possible, the project gives preference to renewable energies, including hydropower and solar panels. Several experimental projects have been implemented and are running in chosen communities to test the viability and functionality of the decentralized and isolated system. Some of them were implemented by CERPCH[2] in conjunction with local suppliers and the results were positive.

1.6. Lessons learned with pilot projects implemented in the area

The projects implemented by CERPCH with micro hydro schemes were successful, but there were a lot of challenges to actually install them in the communities. (Tiago Filho, 2008)

A main lesson learned from the implemented projects in the Amazon region is that it is essential to complement the electricity supply with an activity that can stimulate and maintain the community's economy, so they can afford to pay for their electricity and stay in the countryside instead of migrate to other areas with better life quality. If the indigenous communities are fixed in their original place, they tend to preserve the environment and adapt its own ways of living with the electricity supply, generating a sustainable growth in the region with economic activities that don't have a big impact on the ecosystems.

Secondly, it is very important get the whole community involved in the process, providing workshops, training individuals to make the maintenance of the system and mobilize a group of people to be responsible for it. They need to have a sense of belonging and embrace the project as their own, because this feeling will create concern for the continuity of the energy supply. (Rosa, 2007)

Thirdly, it is crucial to choose the right people to make the tasks needed for the scheme. People that have leadership in the community will make things easier for its installation and development. For the maintenance, the individuals with natural ability for mechanical repair are the most indicated to be trained and do the job, because they already have a better understanding of how machines work. Education can be a serious problem in the installation, since it can create a barrier for the smooth functioning of the scheme.

To conclude, the projects need to be much more than just a micro-hydro scheme to be successful and sustainable. It is essential to think about the three spheres - economic, social and environmental – when you intend to implement this kind of scheme, especially in remote areas with the characteristics described in this case study.

The economic aspects that need to be taken into consideration are – how will the community pay for the electricity supplied? How to guarantee the continuity and maintenance of the scheme throughout the years? How to make the initial investment pay itself in the long term?

The social aspects are: how to involve the stakeholders (community, energy Concession Company, councils) in order to keep the system working properly? How can the energy supply improve the community's life quality? How can the indigenous culture and way of life be preserved with the introduction of new technologies?

The environmental aspects are: What is the best technology to be used in the site that will provoke minimum environmental impact? What can be done to integrate the community's

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[2] Centro Nacional de Referência em Pequenas Centrais Hidrelétricas – National Reference Centre of Small Scale Hydropower Units

growth with the preservation of the forest? Which kind of activity can be stimulated on site without compromising the ecosystems?

2. The project

2.1. Micro hydro for isolated communities

Considering the lessons learned with the pilot projects and the Brazilian scenario, this project intends to attend communities in remote areas in the Amazon region. These communities can be separated in two types: with electric supply provided by a diesel generator and without electric supply.

The project also intends to boost the local economy through the installation of equipment that can help add value to the economic activities developed on site. The equipment would be installed according to the characteristics of the local activities (eg.: mill for grinding grain into flour, water bomb for agriculture, oil extractors for seeds extractivism and so on). This would generate more incomes for the community, helping them to afford to pay for their electricity bills, stimulating their sustainable growth and diminishing migration to urban areas.

Finally, the communities can have their energy from a reliable and renewable source, reducing CO_2 emissions and minimizing the environmental impact in one of the most important natural habitats in the world.

2.2. Hydroelectric potential in the Amazon region

Although the Amazon region has a significant amount of water bodies, more than half are located in a plane region with low velocity flows, where the kinetic energy is not enough to generate power. When the rivers start to go outside this big plane surface, the suitable places for hydro installations starts to appear. This limits enormously the potential in this region, but according to studies developed by CERPCH, there are still several places that could benefit from this technology to generate power. Amazonas state would still have around 10% of the territory of the whole north region with a high potential for the installation of hydropower units. In Acre and Tocantins the potential is the lowest. In Amapá, Mato Grosso, Pará and Rondônia the areas with high potential are spread along the states. In Maranhão and Roraima there is a continuous area that crosses the state with a good hydro electric potential. (CERPCH).

Although previous studies have identified a few parameters, the real challenge now is to cross the information of potential areas with the number of communities that live there. The isolated communities in this region are still being mapped. It is then very difficult to quantify how many of them would be able to be attended by hydropower units.

Isolated communities in the Amazon state

A recent project that involved the program "*Programa Luz para Todos*" and the energy supplier *Manaus Energia*[3] has quantified the number of isolated communities in the state of Amazon. There were 3800 communities identified with a total of 68400 dwellings. The project, entitled "*Projeto Raquel*", intends to map and then supply electricity to the isolated communities with diesel generators in an isolated system scheme. The mapping has already finished and now the economic viability of the diesel installations is being analysed.

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[3] Manaus Energia is the electricity concessionary for the state of Amazon.

Since it has been shown that diesel generators are not the best choice to electrify the communities, this study uses the up-to-date information from Raquel Project to develop an alternative project using hydropower units and a sustainable implementation. The data is used to quantify and calculate with higher precision the amount of CO_2 emissions that will be saved if the thermal generation is substituted by the hydropower units.

Community's profile

The profile of the communities found can be described as follow (Manaus Energia, 2009).

- The main activity is usually extractivism or primary sector activities like fishing. The population is constituted by indigenous groups and there is very little or no money circulation.
- The inhabitants tend to settle along the rivers and lakes, usually very far away from bigger cities. Access is made by boat, since there are no roads connecting these communities. This access is very restricted, because depends on the river conditions that changes with seasons.
- It is an area with very low population density and a big distance to the electricity grid.
- The community is usually composed by a school, community centre, water bomb, small stores and some concentrated dwellings.
- The average number of houses per community is 18, with more than 50% of the communities having between 15-20 houses.
- Approximately 62% of the communities don't have any kind of access to electricity. They use wood piles to cook, get water with buckets and live a very limited life when it comes to comfort.
- Approximately 38% of the communities have small diesel generators paid by the State or the councils. They don't have ANEEL registry and operate without control and in bad conditions. The average operation for these units is from 3 o 6 hours per day, the priority being to supply the school and water bomb. The diesel is usually bought by the community or donated by councils.

These characteristics make an easy case to the implementation of micro hydro units, in particularly the proximity to rivers, a significant distance to the grid supply and the utilisation of inefficient diesel generators that don't cover the communities' daily energy demand.

Saving carbon emissions and transforming it into carbon credits

All the carbon saved with the technology exchange (diesel generators for hydropower units) can be used in the Clean Development Mechanism and generate CERs[4] , helping to fund the project and minimizing the costs with the civil works. Since the newly built run-of-river micro hydropower units emit no GHGs, all GHGs which would have been emitted from the diesel power generation can be considered to be reduced.

2.3. Community simulation: energetic demand

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[4] Certificate of Reduced Emissions

Approximately 10% of the Amazon state's territory has a high hydroelectric potential according to CERPCH. Unfortunately, not all of them will be eligible for a unit installation after a complete site analysis. For this project, a conservative estimate of 5% of the number of communities identified by Raquel Project is used to have a hydropower installation. This results in the number of 190 communities and 3.420 houses being attended by this proposal.

Based on all information gathered, a typical scenario is simulated in order to calculate the energetic demand and consequently the amount of CO_2 that can be saved in the project when a hydropower source is used instead of diesel generators. The standard community was assumed to have 18 houses (average number found in Raquel Project), two small stores, 1 nursery, 1 community centre and 1 school with 2 classrooms.

The electrical demand calculation of a typical rural household is one of the most important technical aspects for this sort of analysis. This gives an overall profile of the expected demand the hydropower installation will have to cope with. The energy availability of the scheme is limited by the head and flow, so the ideal scenario is have a total power that considers the growth of the population and the use of some electrical appliances that consume a lot of power.

Compared to urban houses, rural households usually require considerably less energy, since it has fewer appliances and less people using them at the same time. The main use for electricity in rural areas is for artificial lighting. Usually, electricity is not used for cooking purposes, since the communities tend to prefer the use of wood piles. This increases the capacity to attend a bigger number of families in the same community with the same amount of power. The following table (Table 1) can be used to calculate the demand for a single house:

Appliance	**Power consumption (W)**	**Number of items**	**Demand (watts)**	**Hrs/day**	**Total Wh/day**
Lights	12	8	96	4	384
Fridge	100	1	100	24	2400
Television	100	1	100	3	300
Stereo	50	1	50	3	150
Blender	600	1	600	0.25	150
Fan	120	1	120	4	480
TOTAL			**1066**		**3864**
Max possible peak demand					1066 W
Total energy required per day					3864 Wh
Average demand					161 W
TOTAL ENERGY CONSUMED PER YEAR (KWh)					**1.410,36**

Table 1- Electrical demand for a typical household, based on tables from Langley, 2008.

In this calculation, it was considered only the basic appliances that a rural household would use. The lights considered were all low-energy bulbs and the appliances are energy efficient. Electric showers were not considered, since they can easily be substituted by a thermal solar panel that will provide hot water for the entire day in most of the cases.

Figure 1 shows that the highest demand happens around 700W, when the blender or other similar appliance of high power is working. As this utilisation lasts approximately 10 minutes in the day, this peak is not really threatening. The peak that needs thoroughly consideration is the one occurring at night, but even this one is less than 450W. Another interesting fact is to see that practically the rest of the day, the house only consumes around 100W.

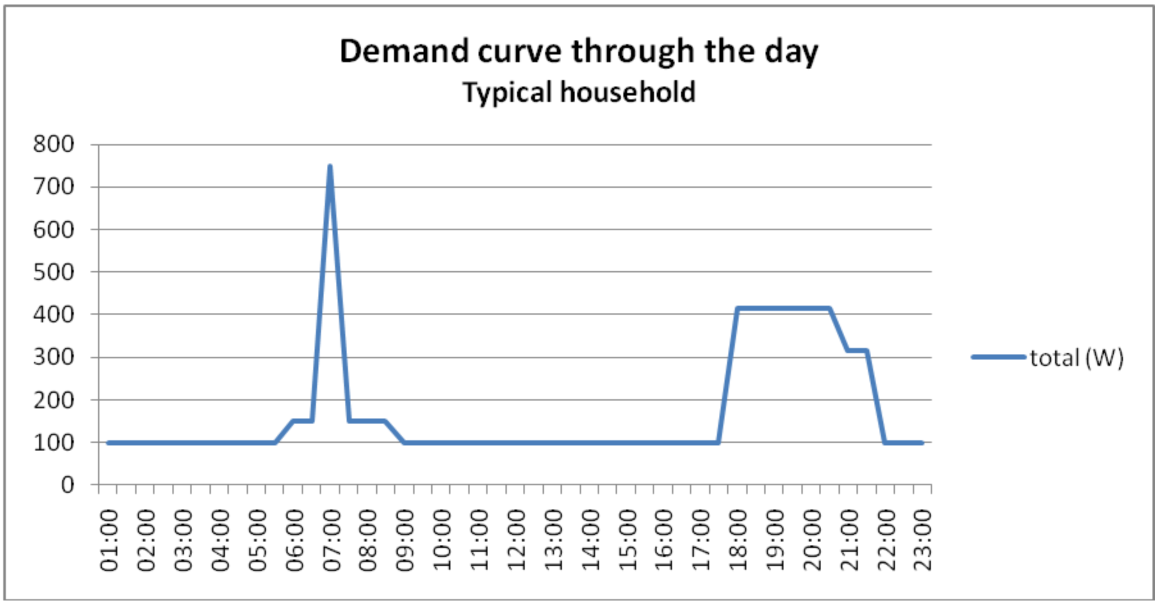

Figure 1- Estimated daily demand curve for a typical rural household. Based on Tiago Filho interview.

Community facilities

To have a realistic calculation of a small community, it is also necessary to consider in the other facilities such as schools, nursery, small stores and community centres, but they won´t add that much in the final number, because their main demand is for lighting, and low-energy bulbs can be used, increasing the load in about 12W per bulb. Any equipment used to support the community activities and economy such as freezers, mills, processors, etc must be in the calculation. In this example, it was considered an average of 300W for the power of the equipment, but of course the number varies depending on what the community needs to develop its activities. External lighting must also be taken into consideration. In this example, the calculation is for a small community with 18 houses, since this was the average number of dwellings identified in the state of Amazonas. The table is showed below (Table 3).

Appliance	Power cons. (W)	Number of items	Demand (watts)	Hrs/day	Total Wh/day
External lighting	12	20	240	6	1440
School lighting	12	10	120	4	480
School - TV	100	1	100	0,5	50
Community centre	12	5	60	3	180
Nursery	12	10	120	4	480
Mill/other equipment	600	1	600	4	2400
Stores - lighting	12	12	144	2	288
Stores - freezer	100	2	200	24	4800
TOTAL			**1584**		**10118**
Max possible peak demand					1584 W
Total energy required per day					10118 W
Average demand					421W
TOTAL ENERGY CONSUMED PER YEAR (KWh)					**3.693,07**

Table 2 - Electrical demand for typical small community, based on tables from Langley, 2008

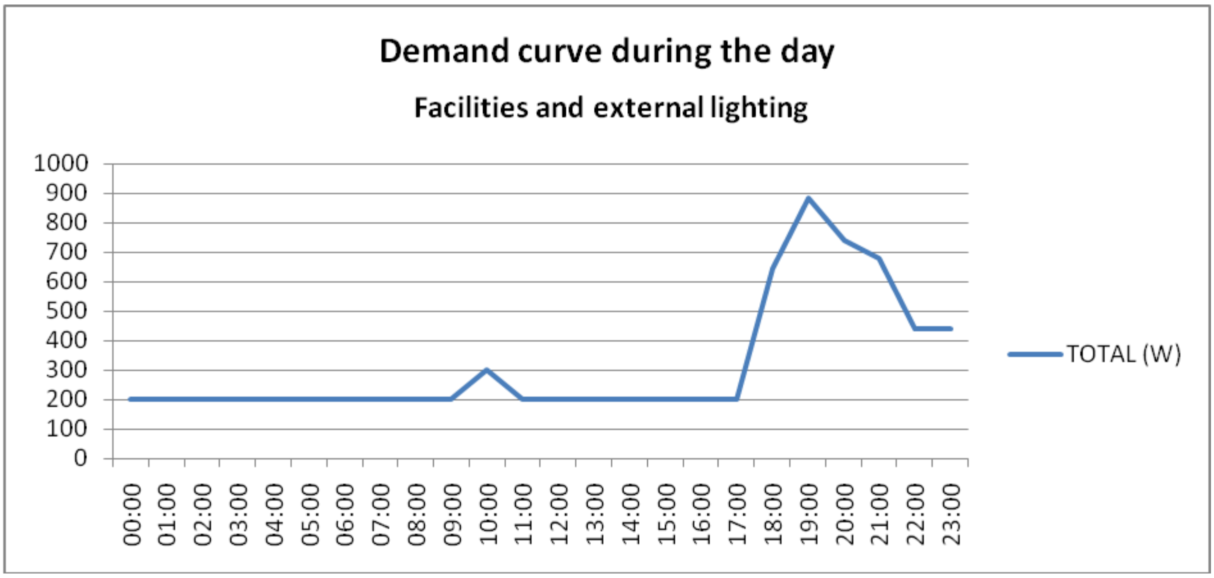

Table 3 – Estimated daily demand curve for a small community, based on Tiago Filho interview.

In Table 3, it is possible to see that the peak during the day reaches 800W at night time. The normal load for the rest of the day is around 200W.
In the final load, it should also be added a percentage for the normal load growth, because the community tends to get bigger and to get more appliances after the electricity is available in the site. It has been estimated a percentage of 20% for the power load growth. This estimate can be used for the period of 5 years.
After all that, it is needed to make a power management with an electronic load controller, a device that manages the supply and diverts the spare energy to other functions when needed. With this device, the electricity use is optimized to its best.

2.4. CDM project calculation

Installed Capacity for hydro units

The calculation for the Installed capacity of the hydro power scheme required for our standard community can be seen below:
Total peak load from houses = 18 (Number of houses) x 410(peak load power) = 7380W
Total peak load for community = 7380 (total houses peak load) + 890 (Community facilities day peak) = 8270W + 20% growth = 9924W = 10KW
Each hydro unit would have to cope with the Installed capacity of 10KW.
Total Installed capacity with the project bundle
10KW x 190 communities =1.900 KW = 1.9MW
Total energy used per year with project bundle
Total per community = 1,410.36 (total energy used for 1 house) x 18 + 3,693.07 = 29,079.55 KWh/year

Energy Baseline

To get approval for the projects under the scheme, a baseline approved by the CDM Executive Board is needed. In the case of this proposal, there is an approved baseline in Brazil called I.A – Electricity generation by the user (CDM - Executive Board, 2009). This category includes renewable energy generation units that provide electricity to a household or a group of households. It is limited to users that are not connected to the grid or are connected in an isolated system where the capacity is less than 15MW. This project would be eligible, since its total Installed capacity is 1.9 MW.

A formula to estimate the annual energy baseline is presented below:

$$Ebl,y = \sum i \ \ EGi,y \ /(1-l)$$

Where:

Ebl,y - Annual energy baseline in kWh;

$\sum i$ - The sum over the group of i renewable energy technologies (e.g. renewable energy technologies for solar home systems, solar pumps) implemented as part of the project activity;

EGi,y - The estimated annual output of the renewable energy technologies of the group of renewable energy technologies installed in kWh;

l - Average technical distribution losses that would have been observed in diesel powered mini-grids installed by public programmes or distribution companies in isolated areas, expressed as a fraction.

For the suggested scenario, this would add to:

Ebl,y = 190 x 29,079.55 / (1- 1/5)

Ebl,y = 6,906,393 KWh

Emissions Baseline

To calculate the emissions, the following formula should be used:

$$BECO2y = EBLy * EFCO2$$

Where:

$BECO2y$ - Emissions in the baseline in year y; t CO_2

$EBLy$ - Annual energy baseline in year y; kWh

$EFCO2$ - emission factor; t CO_2/kWh

For $EFCO2$ a default value of 0.8 kg CO_2-e/kWh, (taken from Appendix B of the simplified modalities and procedures for small-scale CDM project activities) derived from diesel generation units may be used, giving us the following result:

$BECO2y$ = 6,906,393 KWh * 0.8 kg CO_2-e/kWh = 5,525,114 kg CO_2 = **5,525 tonnes of CO_2e**[5]

Carbon credits

With the amount of carbon saved per year defined, it is possible to define the crediting period for the project.

In accordance with paragraph 49 of the modalities and procedures for a clean development mechanism (UNFCCC, 2005), the crediting period may last a maximum of seven or ten years from this start date in the case of renewable and non-renewable crediting period respectively.

It is used the period of 7 years, which can be renewed twice after the end of the first one. First, the initial date for the carbon savings must be defined, meaning that the project needs to be completed in the date indicated in the form. In this example it is considered just for calculation purposes the hypothetical start date of 01/01/2011.

Years (dd/mm/yyyy)	Annual estimation of emission reductions in tonnes of CO_2 e
01/01/2011 – 31/12/2011	5,525
01/01/2012 – 31/12/2012	5,525
01/01/2013 – 31/12/2013	5,525
01/01/2014 – 31/12/2014	5,525
01/01/2015 – 31/12/2015	5,525
01/01/2016 – 31/12/2016	5,525
01/01/2017 - 31/12/2017	5,525
Total estimated reductions CO_2e	**38,675**
Number of years in the first crediting period	7

Monitoring

The monitoring of energy generated per year and consequently of reduced emissions can be monitored through metering the electricity generated by all systems in a sample thereof, as required by the scheme.

Expected operational lifetime of the project activity

According to the market´s producers and historical data from previous installations, the expected lifetime of a micro hydro turbine with correct maintenance is 25 years.

Benefits from this kind of installation

Environmental – The micro-hydro units with run-of-the-river technology provide clean and reliable energy with minimum environmental impact. In addition to CO_2 emission reductions,

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[5] Equivalent Carbon dioxide is the concentration of CO_2 that would cause the same level of radiative forcing (warming through radiation) as a given type and concentration of greenhouse gas, such as methane and nitrous oxide.

the project would also mitigate other pollutants, such as SO2, NOx and particulates associated with power generation from fossil fuels (diesel specifically).

Economic – The technology requires a high initial investment, but has many advantages in the long-term in comparison to the diesel generator. First, it eliminates the dependency on diesel to generate power, saving money on fossil fuels. Second, there is a considerable improvement of power supply quality in the region, through better voltage regulation, reduced system losses and fewer power supply interruptions, allowing the communities to develop economic activities that generate incomes.

Social – The communities' life quality is dramatically improved with the access of electricity, providing better infra-structure for the sites and allowing them to have appliances never used before, such as TVs, freezers and so on. The system also requires training for local workers, creating leaderships and organizing the community to operate the scheme.

2.5. Selling the CERs for the market

The Clean Development Mechanism covers two market segments: the primary market and the secondary market.

The primary market refers to the initial transaction between the project developer and the investor. It is the transaction that carries the CER, the commodity in question, from the project in the developing country to the international market.

The secondary market refers to any further transaction after the primary transaction: the onward sale of the CER until eventually it is bought by the final consumer who will submit it to meet their target. Typically, the buyer in the secondary market (secondary CERs) carries much less risk as the CER is either already in existence, or its delivery is guaranteed in some way with replacement or compensation for non-delivery written into the contract. As a result, the buyer pays much more for the secondary CER.

According to the European Climate Exchange site (European Climate Exchange) the CER trading price in June 2010 for the primary market is at €13.08.

Considering that the project developed in this study saves 38,675 tonnes of carbon in the first 7 years crediting period and that it will sell its CERs in the primary market, the used the average price of €9.74 per tonne of carbon saved can be used. With these numbers defined, the calculation is shown below.

38,675 (tonnes of carbon saved for 1st period) x 13.08 (price per CER) = **€ 505,869.00**

CERs per hydropower unit – € 2,662.47

Average cost per hydropower unit

The costs can vary hugely depending on site characteristics, type of turbine chosen, amount of civil works needed, size of transmission lines, etc. But for calculation effects, it is used an average cost of the kind of installation used in this study. According to Tiago Filho, in Brazil, the average cost of micro hydro units is around R$5,000.00 (five thousand reais) per kilowatt installed. Since the standard unit has a capacity of 10KW, the average cost is estimated to be R$50,000.00.

With the conversion rate for Real x Euro at approximately 2.21, the cost would be of €22,625.00 per unit.

Since the money obtained with the CER per unit was € 2,662.47 it can be concluded that more of 11% of the initial investment could be covered by the CDM scheme.

With the renewal and selling of the other 2 crediting periods during its lifetime, the amount of money saved would reach around 35% of the initial investment, lowering the payback time of the units and making it more economically viable.

This can prove that the CDM scheme can be used as part of the funding for new hydro power units in remote areas, that wouldn't be economically viable in the first place because of the high capital investment.

The CDM scheme is a useful way to transform this kind of project in reality for the isolated communities in Brazil, which could benefit from clean energy and promote their sustainable development, maintaining the integrity of the Amazon forest.

3. Conclusions

3.1. General conclusions

It was possible to prove that micro-hydro schemes can be successfully installed in unelectrified remote areas in Brazil, providing electricity for isolated communities or substituting diesel generators that are not cost-effective and emit carbon dioxides. This study was able to demonstrate that Brazil still has thousands of communities without access to electricity that could benefit from hydropower in small scale and that this option is far more advantageous than the diesel generators.

The pilot projects showed us that the intervention needs to go beyond the energy supply, incorporating a broader scope that includes the community´s welfare and allow its success in the long term. The inhabitants need to have educational support to understand and embrace the program as their own. Their economic activities need to be stimulated or improved to complement their incomes so they can afford to pay for the electricity or some kind of subside needs to be given.

It is very important to note that in all the successful projects, the community has a strong sense of ownership or an external sponsorship, which keeps the project working partially of entirely, independently from the planning or management plan that was established previously. The unsuccessful projects haven´t made a planning that contemplates the time after installation and initial operation and haven´t involved the community in the project´s continuity. Consequently, there were no local leaderships to assume and carry on the "business" after it started to work.

In the specific case of the Amazon communities, it is vital to fix the inhabitants in their sites and preserve their traditions and culture, adapting their lifestyle with the electricity supply and generating a sustainable and environmental-friendly growth.

Finally, this study was able to show that micro hydro units are eligible to be approved in the Clean Development Mechanism scheme, saving carbon emissions that would be generated if diesel units were used to supply electricity in remote areas in Brazil. The registered CERs can be then sold in the carbon trading markets, bringing forth funds that can be used to lower the capital cost of this kind of installation in up to 35%, turning it into a viable option in the financial aspect.

4. Recommendations for future studies

Some difficulties are still preventing the electricity universal access to remote communities in Amazon. There is not reliable information about the quantity and location of the sites that don't have access to electricity in the Amazon region. A detailed study needs to be made in order to map all the communities and the potential technologies that could be used to generate energy. Every case is different and it needs a site assessment to determine the best solution to provide energy.

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